Cow Bayou Special Study - Subwatershed 1.02

Sabine River Authority of Texas

August 31, 1999

Prepared in Cooperation with the Texas Natural Resource Conservation Commission

Under the Authorization of the Texas Clean Rivers Act.

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Introduction

Subwatershed 1.02 contains Cow Bayou (Segment 0511) and covers approximately 194 square miles in the coastal area of the Sabine Basin. The tidally influenced lower portion of the Cow Bayou Subwatershed, up to a point just above Interstate-10, is designated as Segment 0511 in the Texas Surface Water Quality Standards (TSWQS). The standards are established by the Texas Natural Resource Conservation Commission to maintain the quality of the water in the state consistent with public health and enjoyment, protection of wildlife, operation of industries, and economic development of the state.

The Sabine River Authority (SRA) 1996 Assessment of Water Quality identified the Cow Bayou Subwatershed as an area of concern due to poor water quality. Water quality concerns or possible concerns in this Subwatershed include dissolved oxygen, ammonia nitrogen, fecal coliform, and sublethal toxicity. Probable sources of the problems include natural conditions exacerbated by numerous point sources from permitted discharges and runoff from septic tanks and other nonpoint pollution sources. Tidal waterbodies typically have limited assimilative capacity, because of low flows and high dissolved solids. These conditions are made worse by the Subwatershed's high turbidity due to a heavy clay substrate and a large amount of detritus from the deciduous trees common in the area.

Background

The area contains one city with a population greater than 5,000 with an approximate total population of 24,000 people with an estimated 9,000 housing units in the Subwatershed. There are twelve permitted discharges for treated domestic wastewater, however much of the population utilizes on-site systems that have historically functioned poorly if at all. One small treatment system utilizes spray irrigation instead of effluent discharge to the stream. Other discharges to the Subwatershed include five industrial permits and two stormwater permits. Only one of the industrial discharges is located in the upper end of the designated segment, the others are near the confluence with the Sabine River. The only permitted landfill has been closed, and there are two solid waste sites in this Subwatershed. This area also has extensive oilfield activities.

Cow Bayou has been sampled extensively beginning in 1969 and sampled every year since. Fourteen sites had been monitored by 1996, but only two sites were sampled more than four

times. Ambient Toxicity (AT) tests were also conducted in this Subwatershed beginning in 1993. The AT tests conducted in 1993 showed possible toxicity problems due to sublethal effects. Monitoring was expanded to additional sites in an attempt to locate the source of the problem. No sublethal effects have been indicated at the original site since July 1994. Only six out of 44 tests has shown sublethal effects. The sublethal effects may have been the result of natural conditions in tidally influenced areas. Tidally influenced waterbodies can be naturally high in sulfates that can affect the organisms used in the tests.

Due to the extensive use of this waterbody for contact recreation, an intensive study was conducted on the Cow Bayou Subwatershed to identify the sources of water quality impairments. Monitoring included frequent sampling to document both point and non-point sources of fecal coliform, ammonia, and oxygen depleting materials. Sampling was also conducted to substantiate non-compliance with Texas Surface Water Quality Standards.

Study Design

Stream sites and selected permitted discharges in the Cow Bayou Subwatershed were sampled quarterly for biochemical oxygen demand (BOD), total organic carbon (TOC), chemical oxygen demand (COD), nutrients, field parameters, and fecal coliform. All parameters were sampled on the first sampling day of the quarterly program. In order to verify noncompliance with TSWQS, fecal coliform and field parameters were sampled again once per week for a total of five consecutive weeks. To determine which bacteria of the fecal coliform group were present, a differentiation was performed using verification media. Minimum dissolved oxygen measurements were taken within two hours of sunrise during warm weather to verify noncompliance with TSWQS at selected sites.

To help determine whether the fecal coliform concentrations found in Cow Bayou were due to human or animal populations, additional analyses for fecal streptococcus were performed on the stream site samples. Contaminations from animal sources can be indicated by a high number of fecal streptococci as compared to fecal coliform. This analysis must be interpreted with caution since many factors can influence the survival rate of both fecal coliform and fecal streptococci. While the test may show a false negative for animal fecal contamination, it is not likely to

produce a false positive. This information can be quite useful when attempting to determine the source of contamination.

Sampling was also conducted during rainfall events to get information on runoff as well as information on efficiency of WWTP during significant rainfall events. The sampling was conducted during or just after significant rainfall events following a period of dry weather.

Rapid Bioassessments (RBA) were conducted to determine the health of aquatic life at selected stream sites. The RBA procedures followed the methods in EPA/444/4-89-001 *Rapid Bioassessment Protocols for Use in Streams and Rivers*.

Salinity was measured from the surface to the bottom to determine the extent of saltwater intrusion at selected sites in Cow Bayou.

Samples were collected from Cow Bayou at Round Bunch Road (CB1) for ambient toxicity. Additional biomonitoring was conducted for permitted discharges where toxicity tests had not been previously performed.

Flow was measured at selected sites, primarily at small tributaries to Cow Bayou. Flows were measured as close to the sampling event as possible.

A comparison of the Cow Bayou data was made to data collected in Black Bayou, Subwatershed 1.01. Black Bayou is a tidally influenced waterbody with geological characteristics similar to Cow Bayou. Major differences from Cow Bayou are the lack of permitted discharges and a very sparse population in the Black Bayou watershed. The low level of human activities in the Black Bayou Subwatershed should indicate what the water quality conditions in Cow Bayou would be if it was not impacted by human activities.

Cow Bayou Sampling Sites

Stream Sites

SRA ID	Description	TNRCC #	Parameter Set
CB7	Cow Bayou at Jasper Co. Rd 826	16058	Q, RF, DO
CB6	Cow Bayou at SH 12	10337	Q, RF, DO
CB5	Cow Bayou at IH-10	10457	Q, RF, DO
CB4	Cow Bayou at Fm 1442(North Crossing)	13781	Q, RF, DO
TG	Terry Gully at IH-10	16040	Q, RF, DO
CC	Cole Creek at IH-10	16060	Q, RF, DO
CB3	Cow Bayou at FM 105	10453	Q, RF, DO
CNB	Coons Bayou at SH 87	16052	Q, RF, DO
CB1	Cow Bayou at Round Bunch Rd	10449	Q, RF, DO

Domestic Wastewater Treatment Plants

SRA ID	Description	TNRCC #	Parameter Set
CW13	Jasper Co. WCID WWTP Outfall 001	16045	Q, RF
CW8	PCS Development Company WWTP Outfall 001	16064	Q, RF
CW7	TX Dot WWTP Outfall 001	16066	Q, RF
CW12	David K Moore Crawdads WWTP Outfall 001	16050	Q, RF
CW11	Mauriceville Jr. High WWTP Outfall 002	16069	Q, RF
CW10	Oak Terrace MHP WWTP Outfall 001	16062	Q, RF
CW9	Oakleaf Park WWTP (Non-discharge)	16065	Q, RF
CW6	SRA WWTP Outfall 001	16042	Q, RF
CW5	Orangefield ISD WWTP Outfall	16063	Q, RF
CW1	City Of Bridge City WWTP Outfall 001	16068	Q, RF
CW2	Sunrise East Apts. WWTP Outfall 001	16071	Q, RF
CW4	Bayou Pines WWTP Outfall	16070	Q, RF
CW3	Blacksher Dev. Corp. WWTP Outfall 001	16067	Q, RF

Industrial Wastewater Treatment Plants

SRA ID	Description	TNRCC #	Parameter Set
CI6	TX Polymer Outfall 001	16072	AT
CI2	Print Pak Inc. Outfall	16075	AT

Parameter Set Codes: Q = Quarterly, RF = Rainfall Event Sampling, DO = Minimum Dissolved Oxygen measurements, At = Ambient Toxicity

Figure 1. Sample Locations in the Cow Bayou Watershed

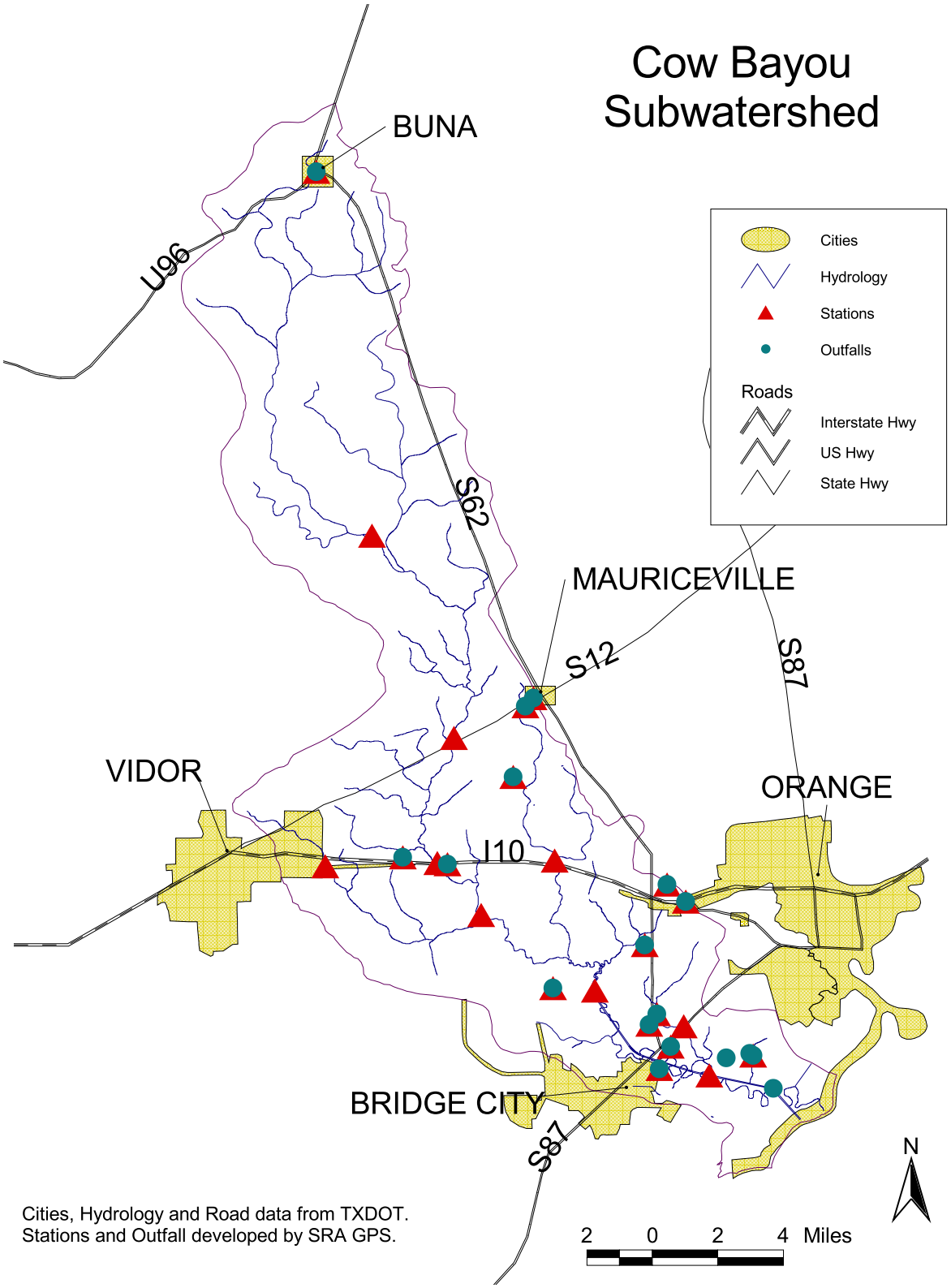


Figure 2. Land Use in the Cow Bayou Subwatershed

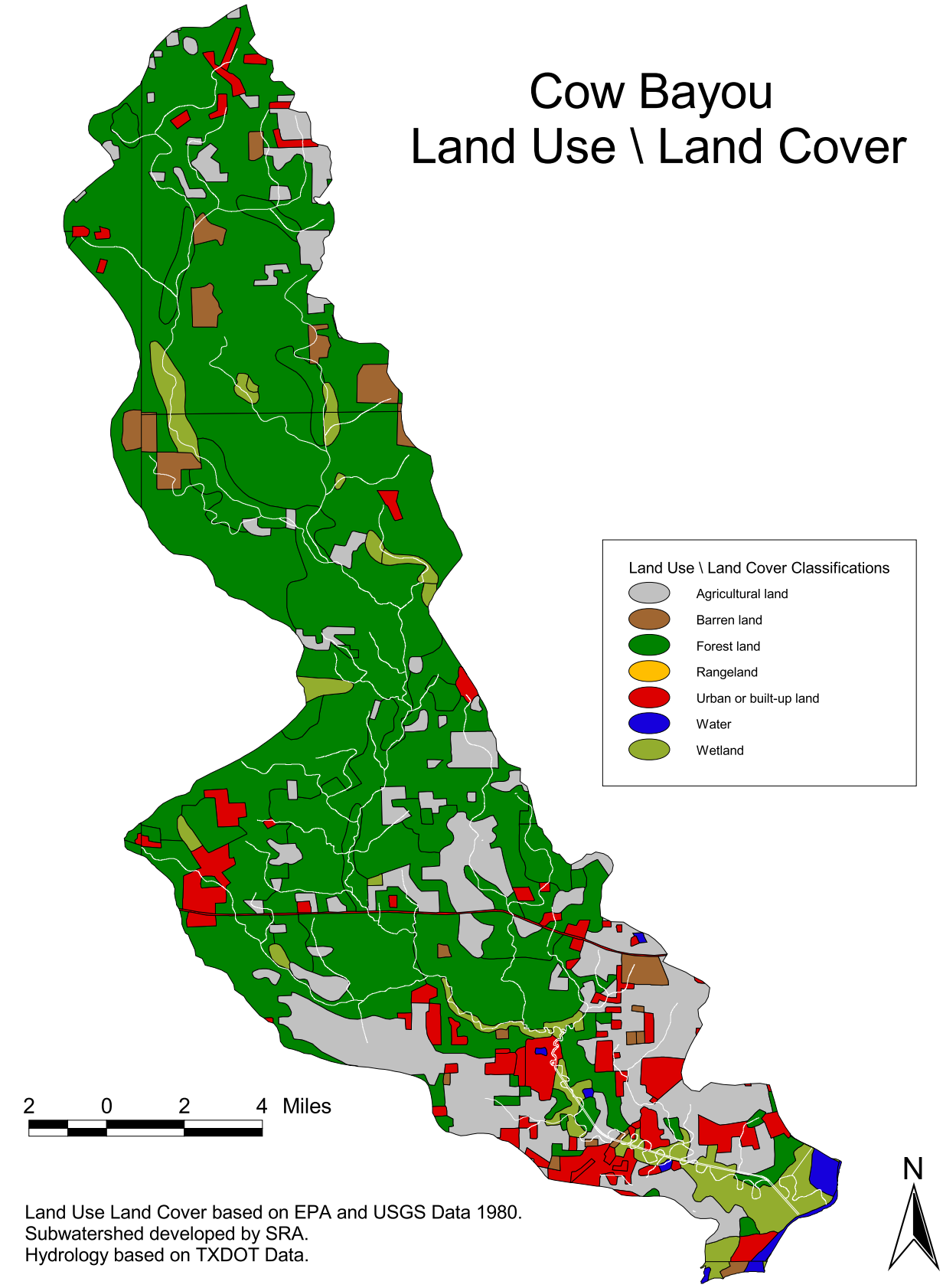
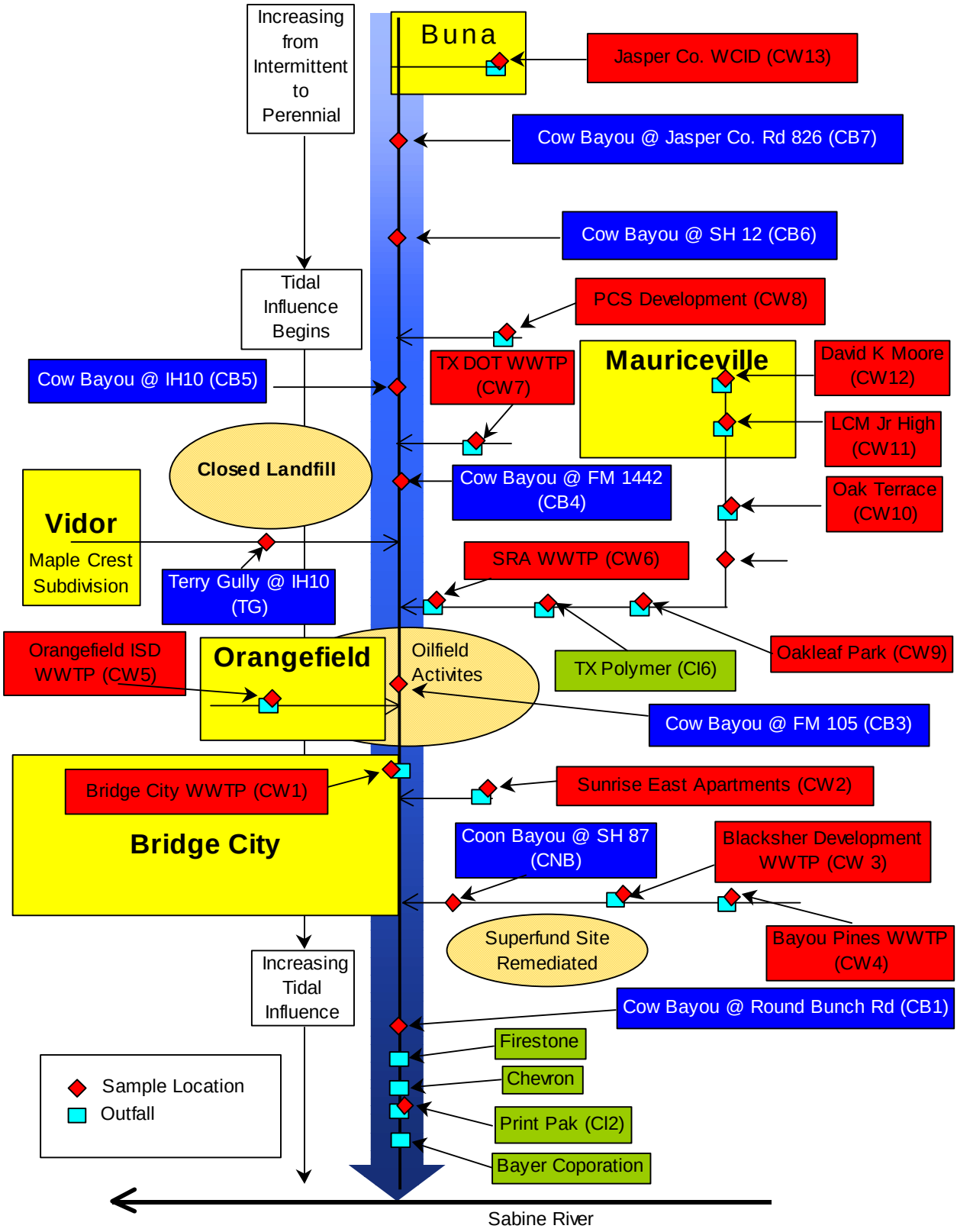
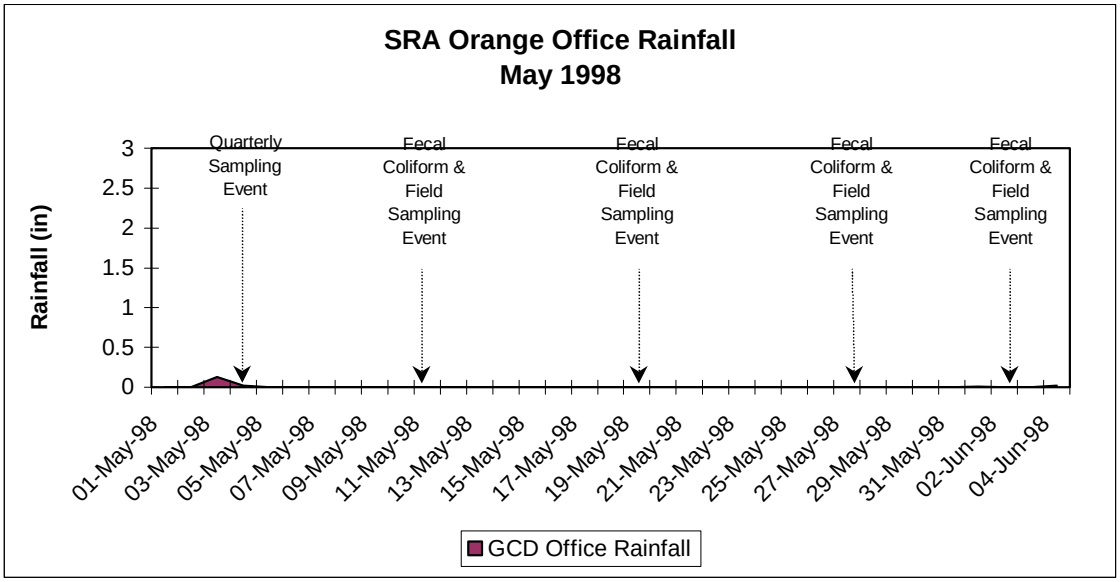


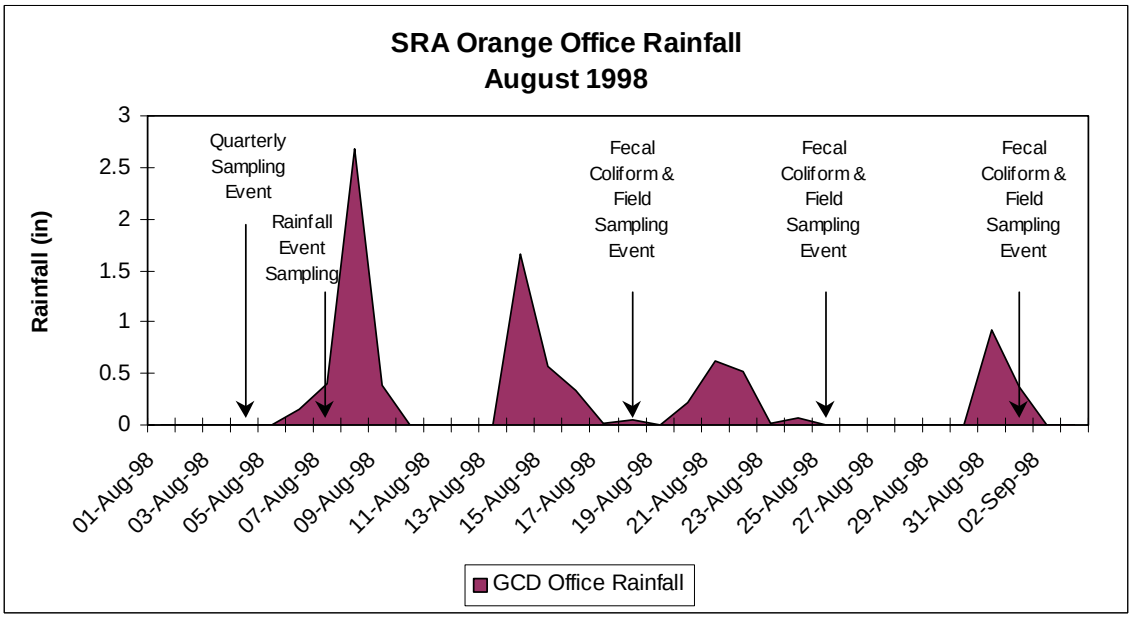
Figure 3. Schematic Diagram of Cow Bayou Subwatershed

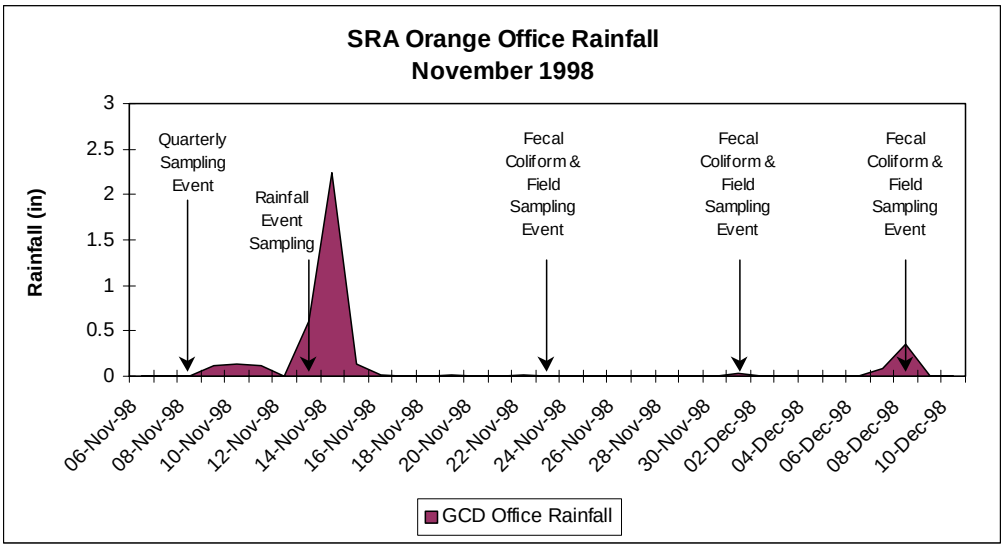


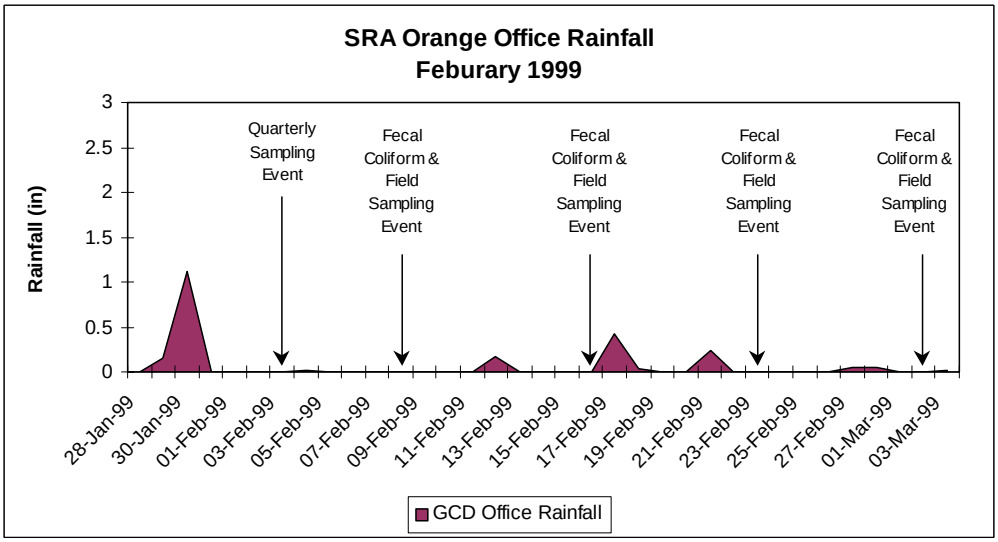
Sampling Periods and Rainfall Events

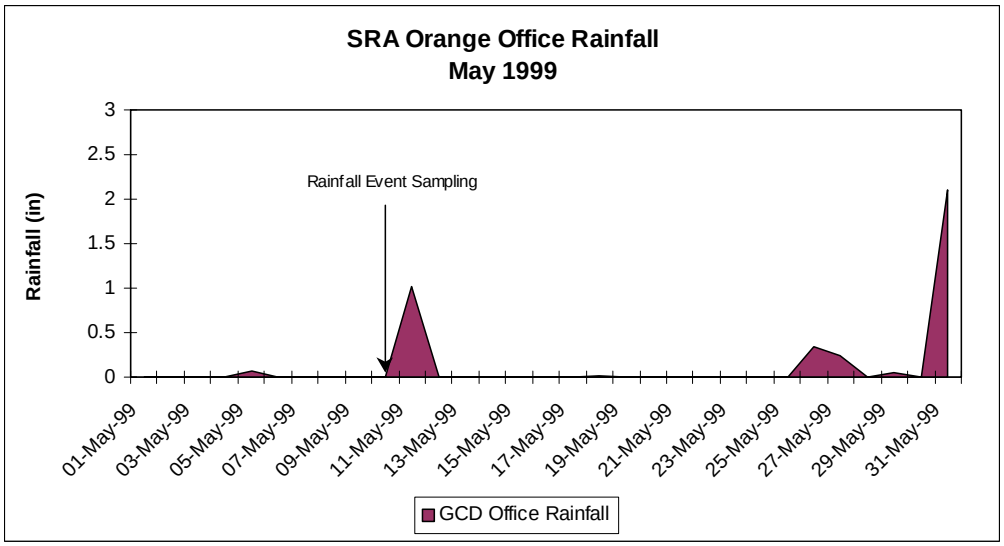
Rainfall was measure at the SRA Gulf Coast Division Office near Orange, Texas. The rainfall events were not evenly distributed throughout the Subwatershed and because of this, not all sites were sampled during every rainfall event. Rainfall event sampling was performed only when the field biologists determined runoff from rainfall had occurred. The distribution of the rainfall is more readily apparent in the flow measurements.





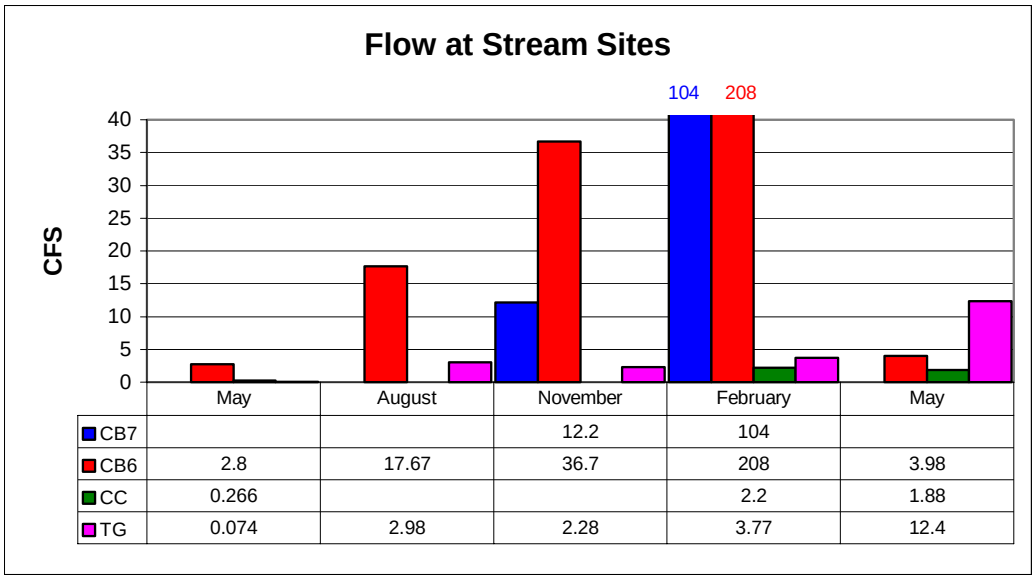

SRA Orange Office Rainfall
November 1998
Rainfall (in)
Quarterly Sampling Event
Rainfall Event Sampling
Fecal Coliform & Field Sampling Event
Fecal Coliform & Field Sampling Event
Fecal Coliform & Field Sampling Event
GCD Office Rainfall


SRA Orange Office Rainfall
Feburary 1999
Rainfall (in)
Quarterly Sampling Event
Fecal Coliform & Field Sampling Event
Fecal Coliform & Field Sampling Event
Fecal Coliform & Field Sampling Event
Fecal Coliform & Field Sampling Event
GCD Office Rainfall

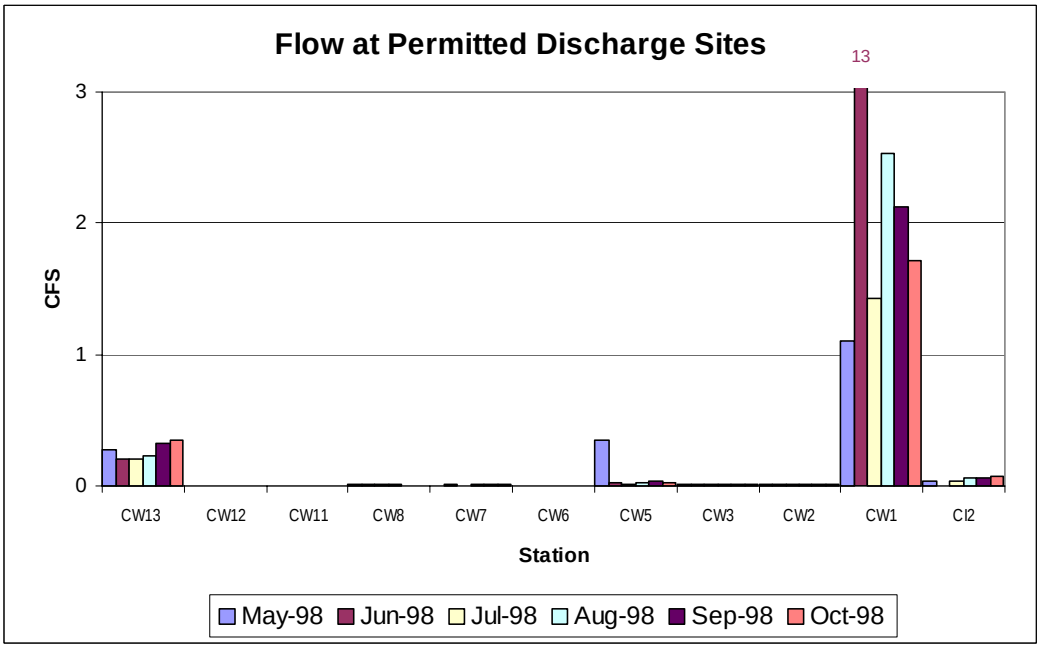

SRA Orange Office Rainfall
May 1999
Rainfall (in)
Rainfall Event Sampling
GCD Office Rainfall

Flow

Flow measured at stream sites ranged from 208 cubic feet per second (cfs) at CB6 to less than 1 cfs at TG. The CB6 site was a gauging station for the U. S. Geological Society from 1952 to 1986. The maximum flow recorded was 4,460 cfs, but the average daily flow was approximately 103 cfs. The median or normal flow during the period of record was about 7 cfs. The only permitted discharge site with a flow greater than 1 cfs was CW1. The maximum flow recorded at CW1 was 13 cfs. All other permitted discharge sites were less than 1 cfs and most were less than 0.01 cfs. The CW9 treatment plant utilizes spray irrigation and has a "no discharge" permit.



	May	August	November	February	May
CB7			12.2	104	
CB6	2.8	17.67	36.7	208	3.98
CC	0.266			2.2	1.88
TG	0.074	2.98	2.28	3.77	12.4



Results

Biochemical Oxygen Demand

The biochemical oxygen demand (BOD) is a measure of the amount of oxygen removed from aquatic environments by aerobic micro-organisms for their metabolic requirements. BOD is used to determine the level of organic pollution of a stream or lake. The BOD in the stream sites ranged from 13 mg/L at Station TG to less than 2 mg/L at several sites. Stream sites typically have low BOD values, usually less than 5 mg/L. BOD values were low at most stream sites during most of the quarterly sampling events. Increases in BOD were observed during the rainfall sampling (May 10, 1999) at all sites. The largest increases were observed in stream sites receiving runoff from areas with concentrated on-site septic tank systems. Elevated BOD values were recorded at several discharge sites, including CW13, CW12, CW10, CW9, and CW4. With the exception of CW12, the BOD values were consistently higher at these sites than the other discharge sites for all sampling events.

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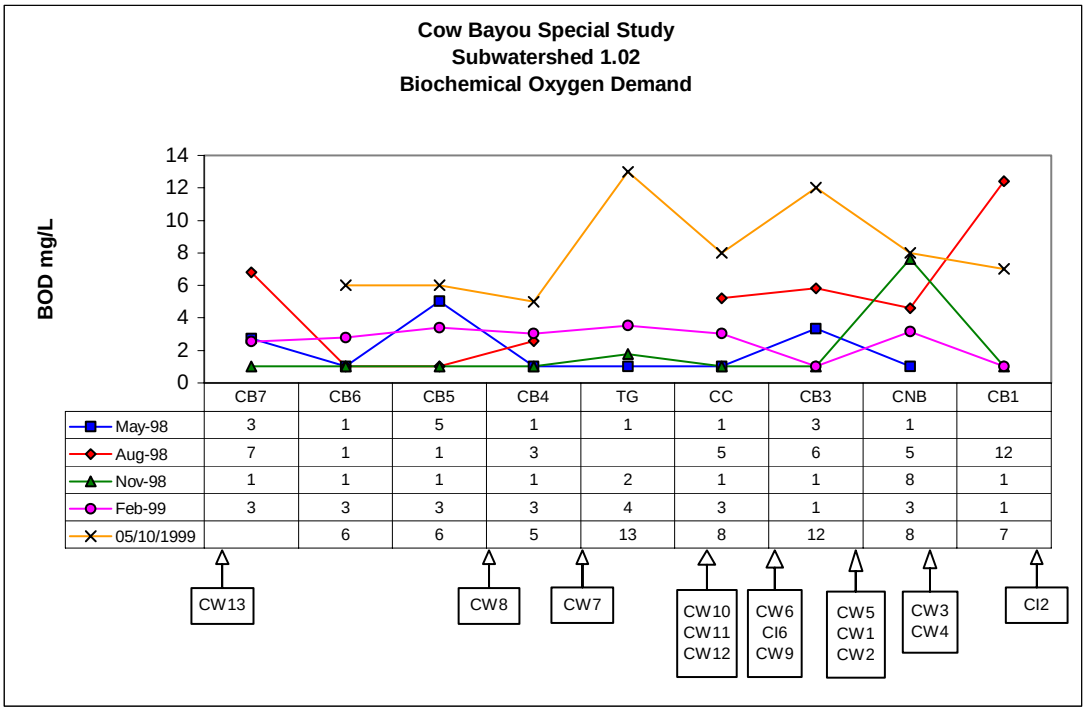
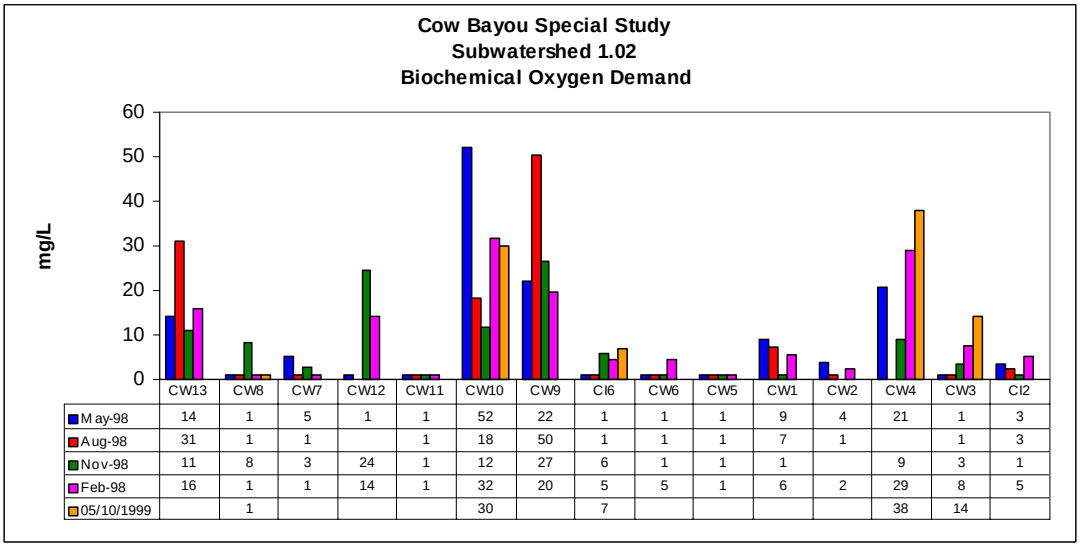


	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
May-98	3	1	5	1	1	1	3	1	
Aug-98	7	1	1	3		5	6	5	12
Nov-98	1	1	1	1	2	1	1	8	1
Feb-99	3	3	3	3	4	3	1	3	1
05/10/1999		6	6	5	13	8	12	8	7



	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
May-98	14	1	5	1	1	52	22	1	1	1	9	4	21	1	3
Aug-98	31	1	1		1	18	50	1	1	1	7	1		1	3
Nov-98	11	8	3	24	1	12	27	6	1	1	1		9	3	1
Feb-98	16	1	1	14	1	32	20	5	5	1	6	2	29	8	5
05/10/1999		1				30		7					38	14	

Total Organic Carbon

Total organic carbon (TOC) is another measure of organic material in water. Stream values are usually less than 10 mg/L. Values for TOC at the stream sites ranged from 33 mg/L at Station CB7 to 6 mg/L at CB1. The average value in the stream samples was 17 mg/L. The trend for TOC actually decreased from upstream to downstream. This is likely due to the high amount of detrital material being produced by the heavily forested area in the upper part of the Subwatershed. The organic material is broken down as it moves downstream and some of it is consumed by the aquatic community. Rainfall events appear to have little impact on the stream site TOC values. TOC values at discharge sites CW9 and CW10 were typically higher than stream site values. The highest value was 52 mg/L at CW9. No impact was observed at the stream sites from the discharge sites.

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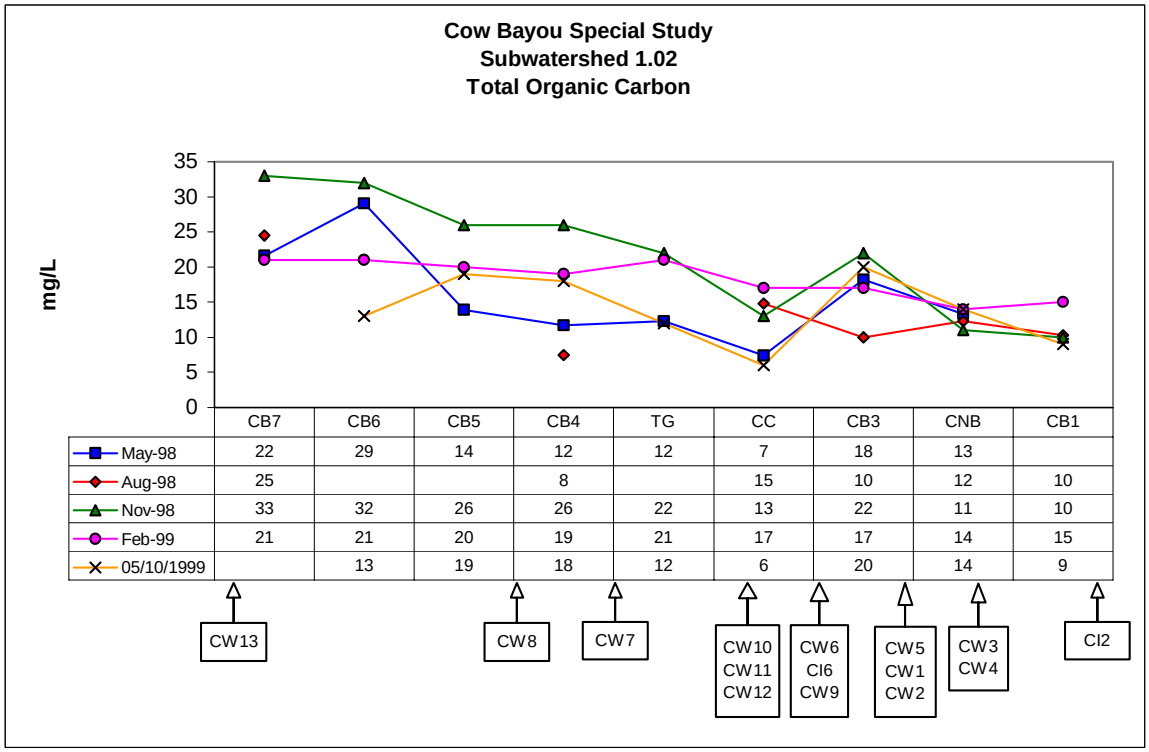
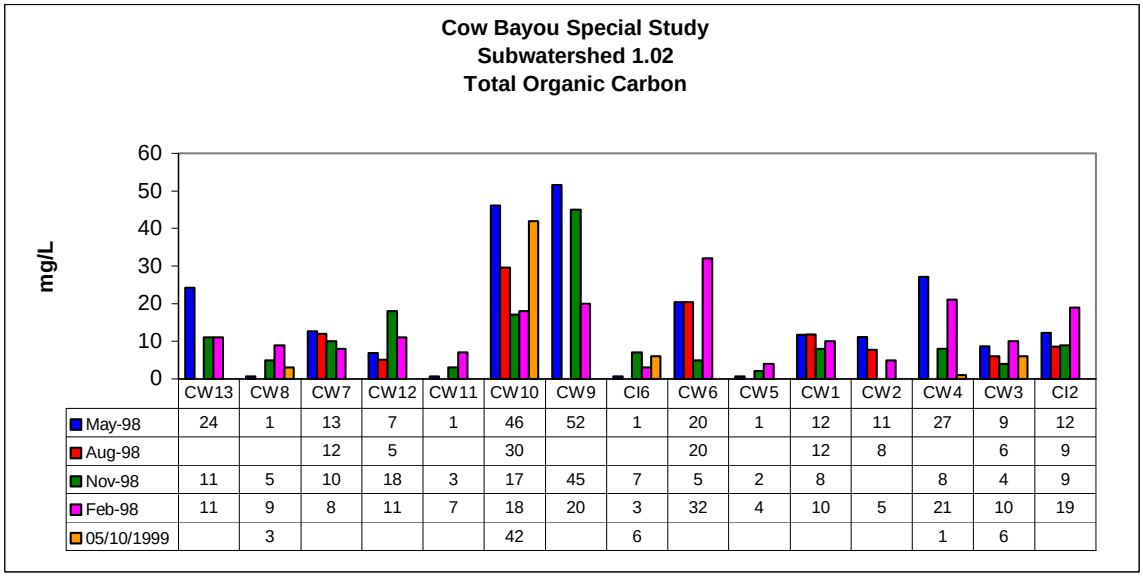


	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
May-98	22	29	14	12	12	7	18	13	
Aug-98	25			8		15	10	12	10
Nov-98	33	32	26	26	22	13	22	11	10
Feb-99	21	21	20	19	21	17	17	14	15
05/10/1999		13	19	18	12	6	20	14	9

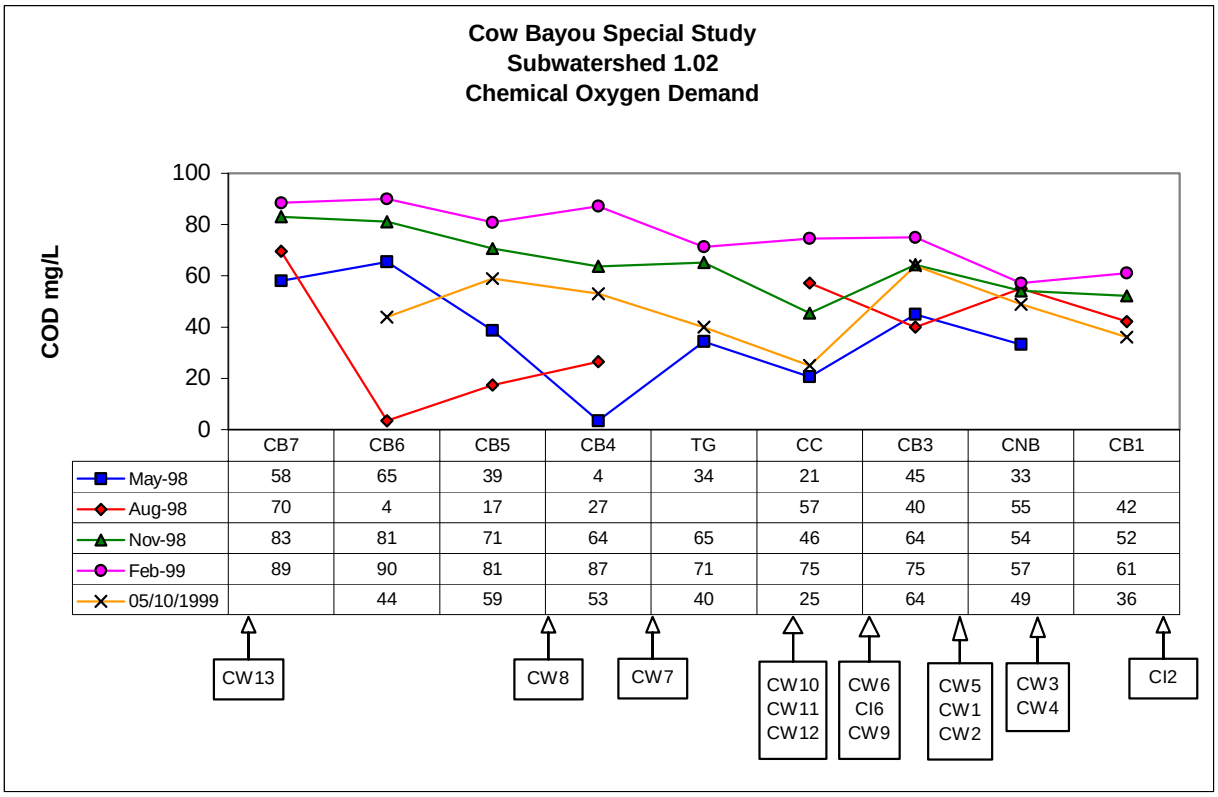


	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
May-98	24	1	13	7	1	46	52	1	20	1	12	11	27	9	12
Aug-98			12	5		30			20		12	8		6	9
Nov-98	11	5	10	18	3	17	45	7	5	2	8		8	4	9
Feb-98	11	9	8	11	7	18	20	3	32	4	10	5	21	10	19
05/10/1999		3				42		6					1	6	

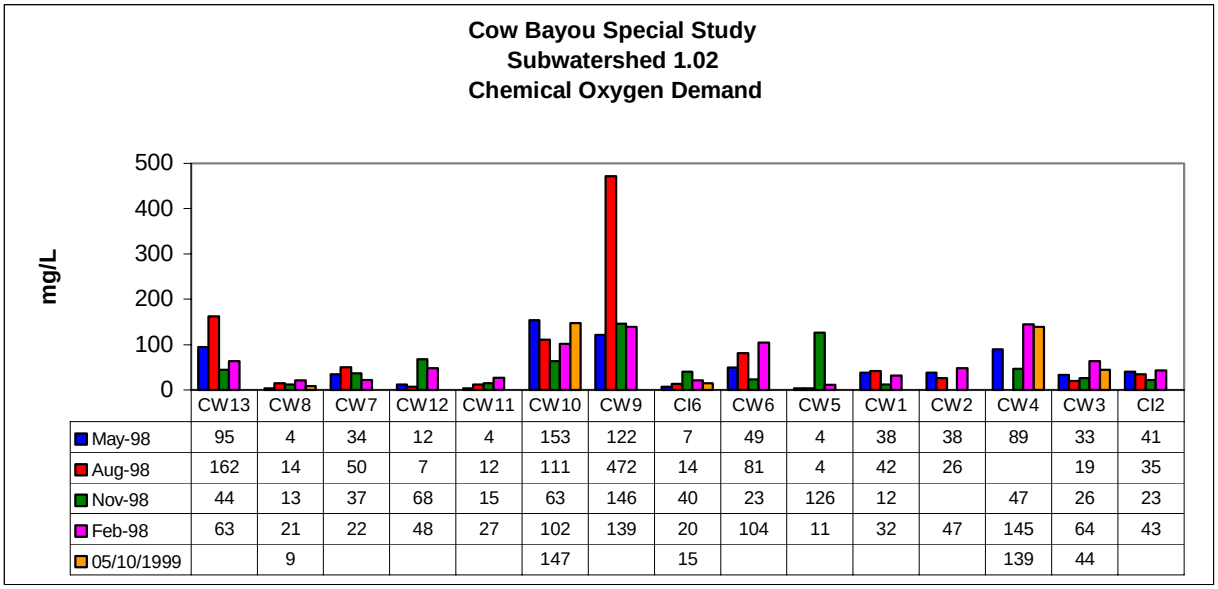
Chemical Oxygen Demand

Chemical Oxygen Demand (COD) is a measure of the amount of organic substances in water or wastewater. COD values are typically higher than BOD values and COD values in streams are normally less than 50 mg/L. The range of values in the stream sites was from 90 mg/L at CB6 to 4 mg/L at CB6 and CB4. Although a few stream site values indicated some organic loading, the median value was 56 mg/L and the average value was 59 mg/L. This would indicate no major organic loading problems. COD values at the discharge sites ranged from 472 mg/L at CW9 to 4 mg/L at several sites. Downstream sites appear to be impacted slightly from the elevated levels at the permitted discharge sites.

Special Study on Subwatershed 1.02 – Cow Bayou



	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
May-98	58	65	39	4	34	21	45	33	
Aug-98	70	4	17	27		57	40	55	42
Nov-98	83	81	71	64	65	46	64	54	52
Feb-99	89	90	81	87	71	75	75	57	61
05/10/1999		44	59	53	40	25	64	49	36



	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
May-98	95	4	34	12	4	153	122	7	49	4	38	38	89	33	41
Aug-98	162	14	50	7	12	111	472	14	81	4	42	26		19	35
Nov-98	44	13	37	68	15	63	146	40	23	126	12		47	26	23
Feb-98	63	21	22	48	27	102	139	20	104	11	32	47	145	64	43
05/10/1999		9				147		15					139	44	

Ammonia

Although there are no stream standards for ammonia, it can be toxic to fish in very small amounts. The toxicity is dependent on pH and increases as pH increases. Stream values from natural sources of ammonia are rarely above 1 mg/L. The highest value for ammonia in the stream sites was 0.6 mg/L at CNB and no toxic levels were found at any of the stream sites. At the discharge sites, the highest ammonia value was 30 mg/L at CW7. Although elevated values were observed at Stations CW8, CW12, CW6, CW4, and CW2, almost no impact was observed on the downstream sites.

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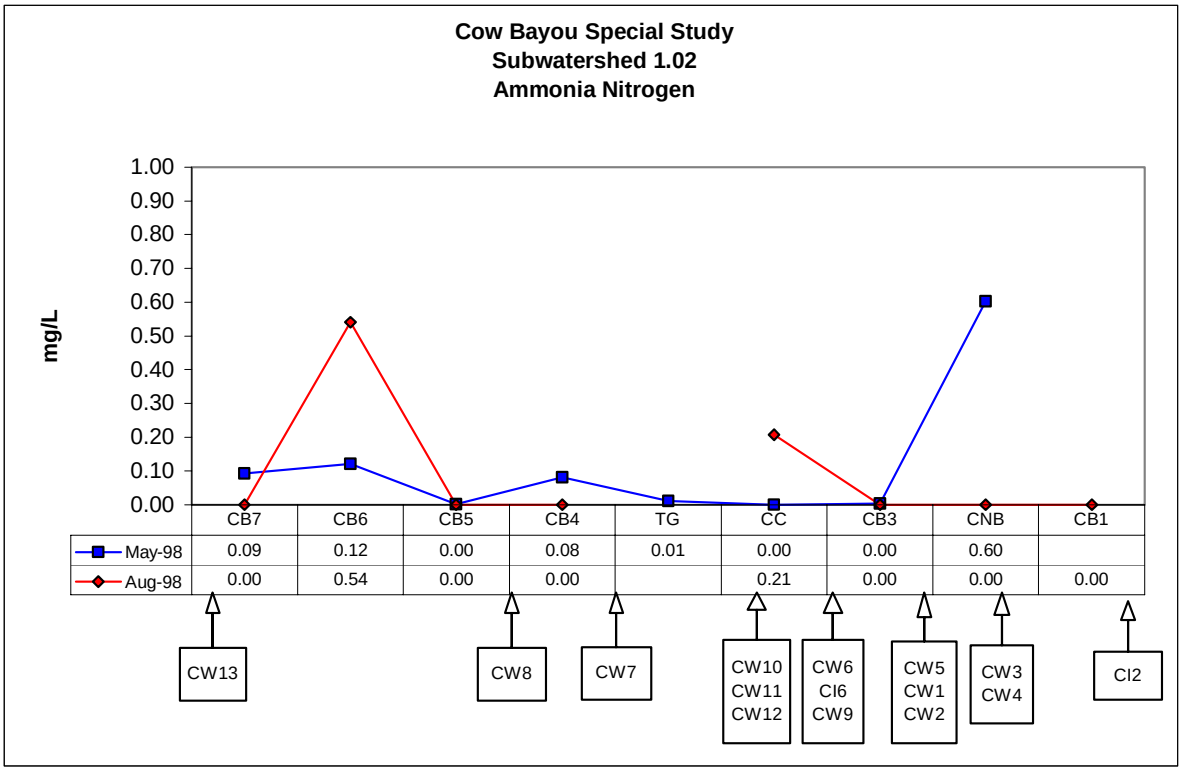
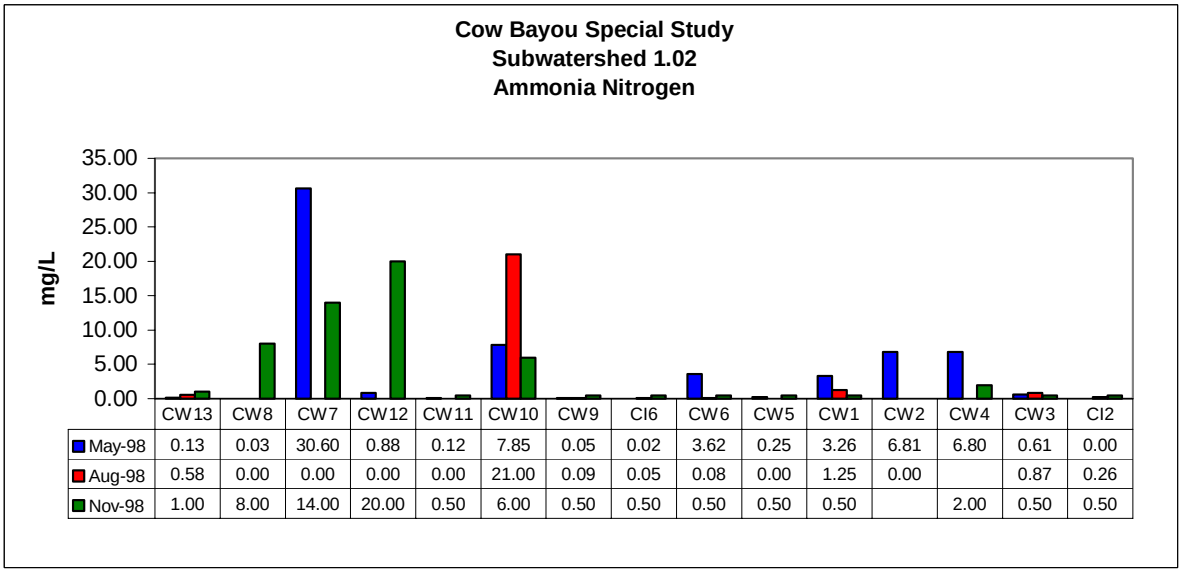


	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
May-98	0.09	0.12	0.00	0.08	0.01	0.00	0.00	0.60	
Aug-98	0.00	0.54	0.00	0.00		0.21	0.00	0.00	0.00

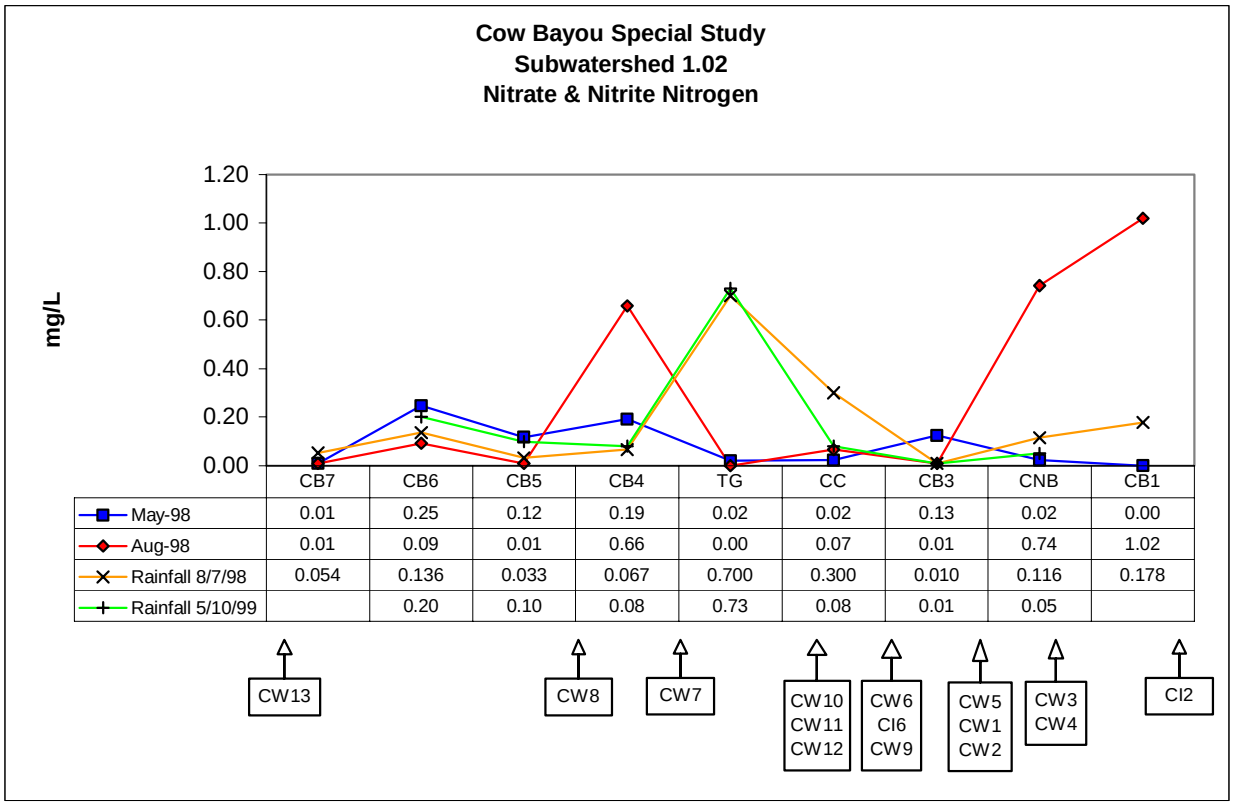


	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
May-98	0.13	0.03	30.60	0.88	0.12	7.85	0.05	0.02	3.62	0.25	3.26	6.81	6.80	0.61	0.00
Aug-98	0.58	0.00	0.00	0.00	0.00	21.00	0.09	0.05	0.08	0.00	1.25	0.00		0.87	0.26
Nov-98	1.00	8.00	14.00	20.00	0.50	6.00	0.50	0.50	0.50	0.50	0.50		2.00	0.50	0.50

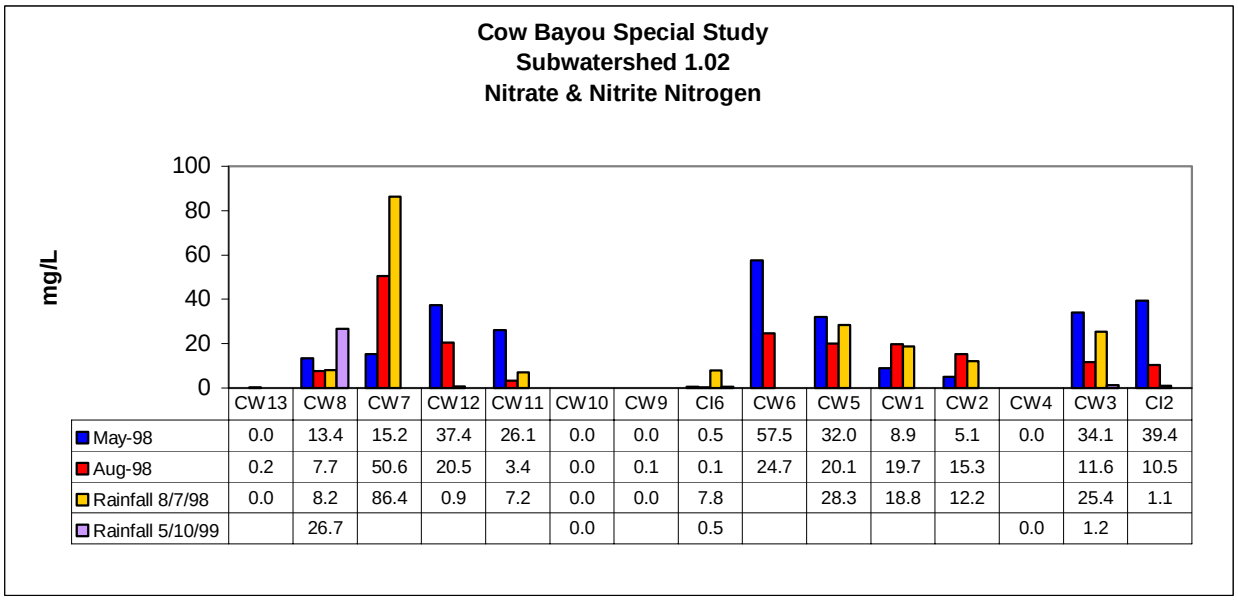
Nitrate and Nitrite

The primary concern for nitrogen compounds in water is nutrient enrichment that can lead to excessive growth of unwanted plants. High nitrates in drinking water can cause digestive disturbances in people and high nitrites can cause toxicity in fish. Levels of nitrate and nitrite in streams should not exceed 10 mg/L, although no limits are listed in TSWQS. The highest value in the stream was 1.02 mg/L at CB1. The average value was well below 1 mg/L at all stream sites. Elevated values during the rainfall sampling events at TG indicate impact from nonpoint sources such as the on-site septic systems in that area. Nitrate values were elevated at Stations CW8, CW7, CW11, CW12, CW6, CW5, CW1, CW3, and CI2, however no limits have been set in TSWQS. The highest value was 86 mg/L at Station CW7. The low values at the stream sites indicate very little impact from the permitted discharges even during rainfall events.

Special Study on Subwatershed 1.02 – Cow Bayou



	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
May-98	0.01	0.25	0.12	0.19	0.02	0.02	0.13	0.02	0.00
Aug-98	0.01	0.09	0.01	0.66	0.00	0.07	0.01	0.74	1.02
Rainfall 8/7/98	0.054	0.136	0.033	0.067	0.700	0.300	0.010	0.116	0.178
Rainfall 5/10/99		0.20	0.10	0.08	0.73	0.08	0.01	0.05	

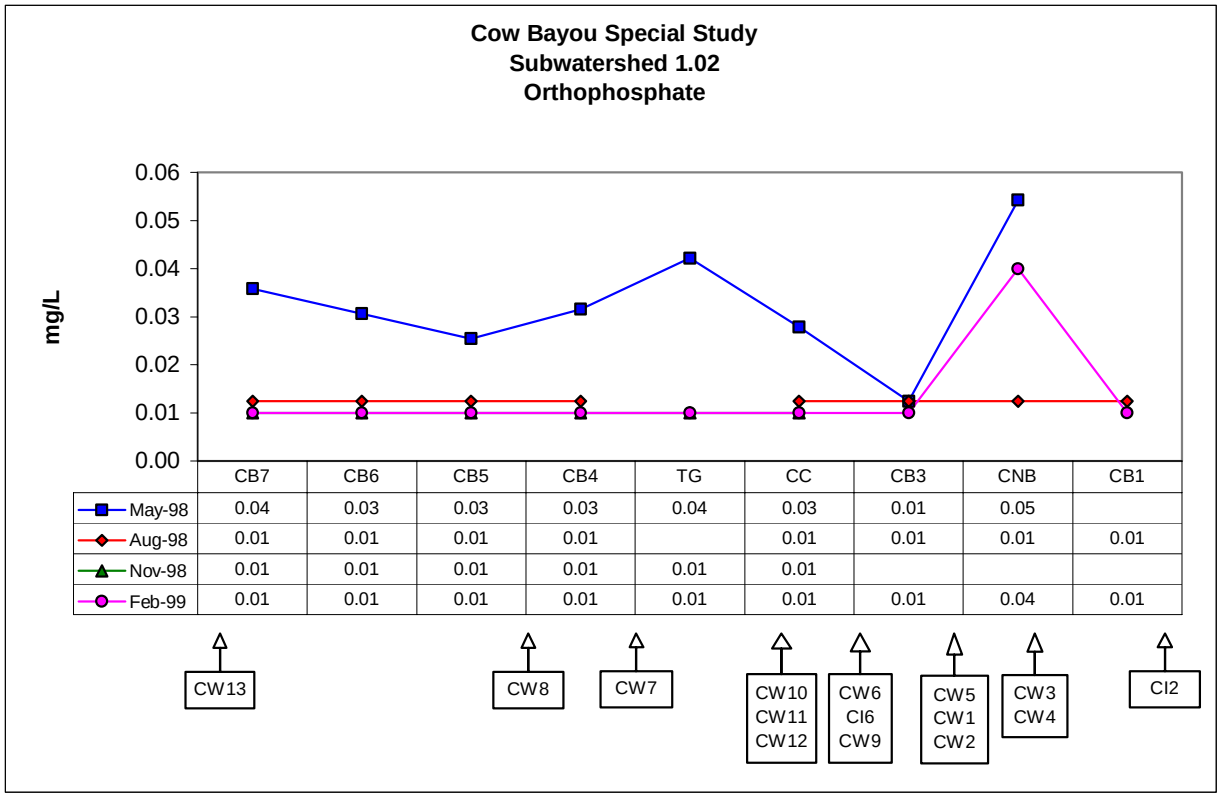


	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
May-98	0.0	13.4	15.2	37.4	26.1	0.0	0.0	0.5	57.5	32.0	8.9	5.1	0.0	34.1	39.4
Aug-98	0.2	7.7	50.6	20.5	3.4	0.0	0.1	0.1	24.7	20.1	19.7	15.3		11.6	10.5
Rainfall 8/7/98	0.0	8.2	86.4	0.9	7.2	0.0	0.0	7.8		28.3	18.8	12.2		25.4	1.1
Rainfall 5/10/99		26.7				0.0		0.5					0.0	1.2	

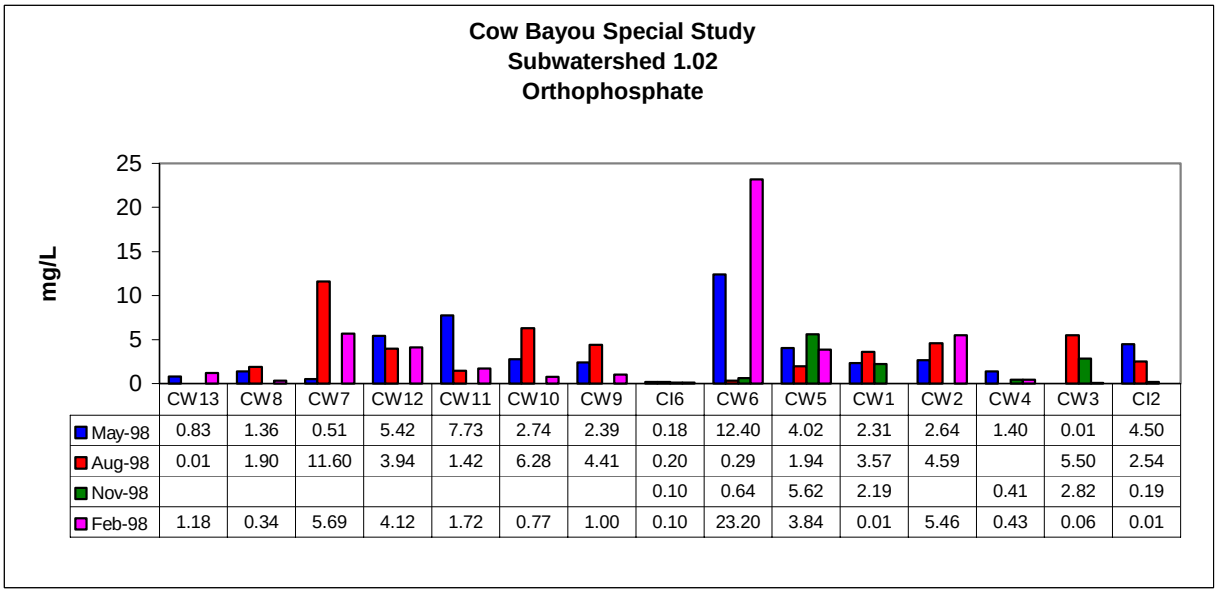
Orthophosphate

There are no stream standards for orthophosphate and the greatest threat it poses for waterbodies is nutrient enrichment. The presence of even small amounts (1 mg/L) in water can lead to excessive growth of aquatic weeds and algae. Orthophosphate values at the stream sites were usually well below 0.1 mg/L with the maximum value of 0.05 mg/L at CNB. Impact from nonpoint sources was indicated by elevated values during rainfall events at TG that showed a high of 1.05 mg/L. The values were typically higher at the permitted discharge sites with Stations CW7, CW12, CW11, CW10, CW6, CW5, and CW2 showing the highest values. The highest value was 23 mg/L at Station CW6. During rainfall events, the orthophosphate values from the point sources did not appear to impact the stream sites.

Special Study on Subwatershed 1.02 – Cow Bayou

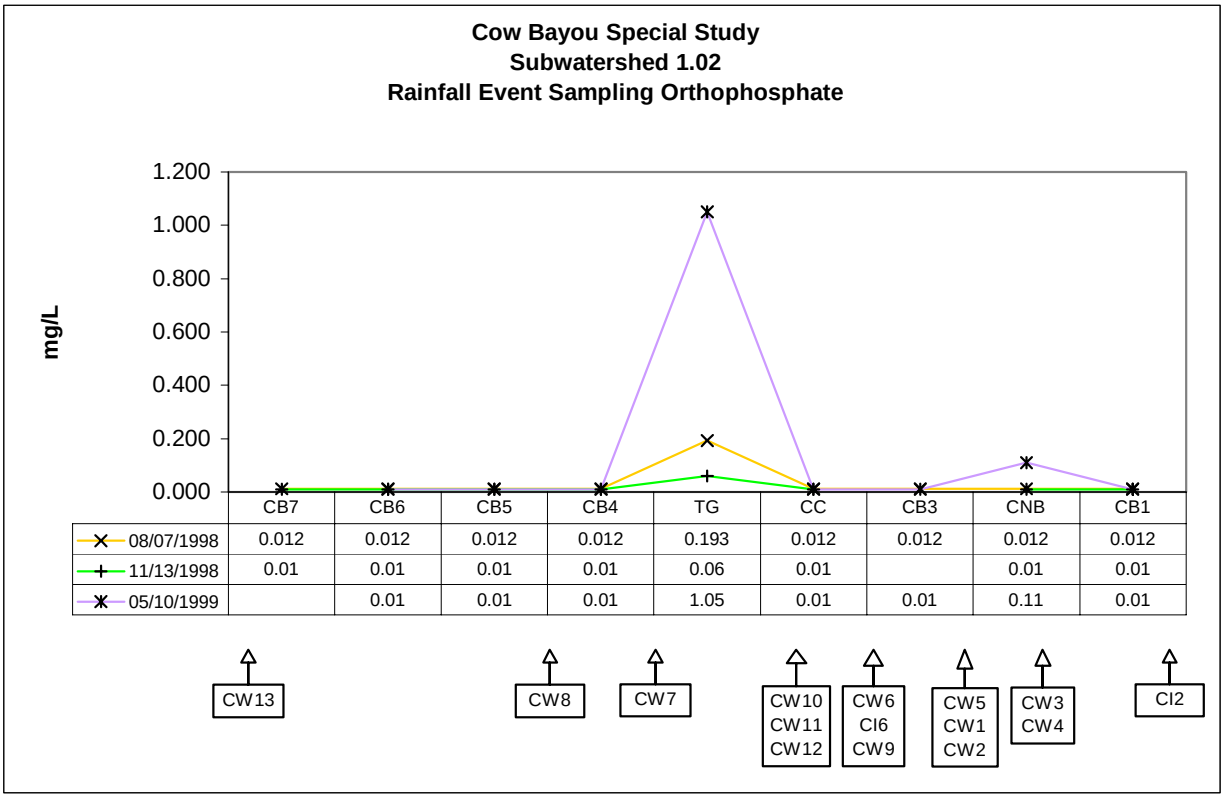


	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
May-98	0.04	0.03	0.03	0.03	0.04	0.03	0.01	0.05	
Aug-98	0.01	0.01	0.01	0.01		0.01	0.01	0.01	0.01
Nov-98	0.01	0.01	0.01	0.01	0.01	0.01			
Feb-99	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.01

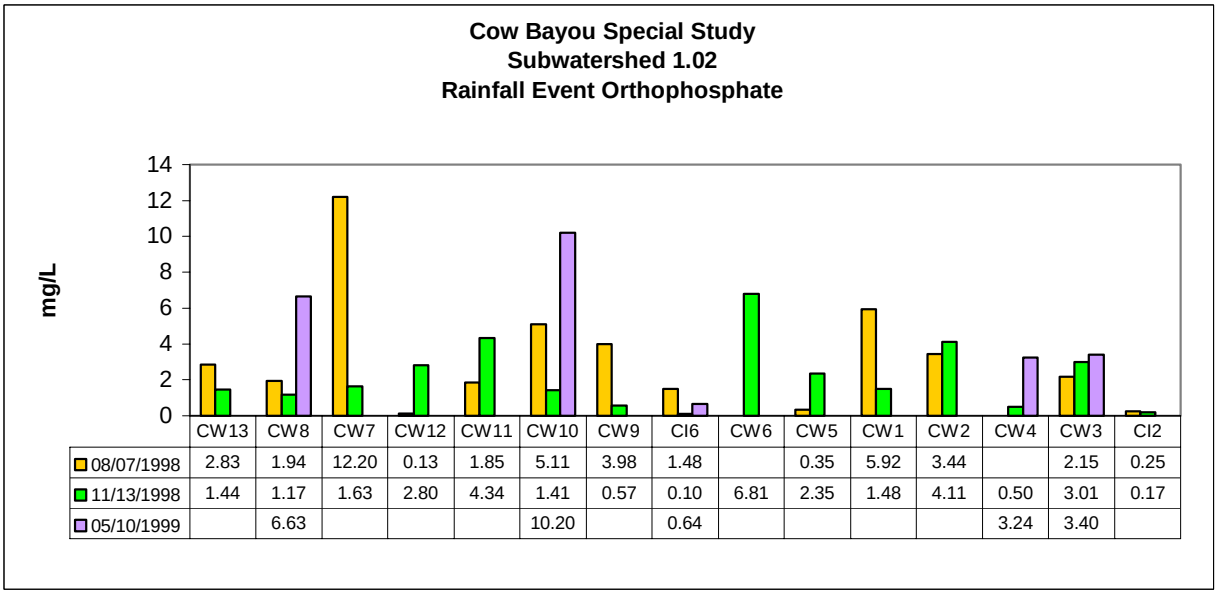


	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
May-98	0.83	1.36	0.51	5.42	7.73	2.74	2.39	0.18	12.40	4.02	2.31	2.64	1.40	0.01	4.50
Aug-98	0.01	1.90	11.60	3.94	1.42	6.28	4.41	0.20	0.29	1.94	3.57	4.59		5.50	2.54
Nov-98								0.10	0.64	5.62	2.19		0.41	2.82	0.19
Feb-98	1.18	0.34	5.69	4.12	1.72	0.77	1.00	0.10	23.20	3.84	0.01	5.46	0.43	0.06	0.01

Special Study on Subwatershed 1.02 – Cow Bayou



	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
08/07/1998	0.012	0.012	0.012	0.012	0.193	0.012	0.012	0.012	0.012
11/13/1998	0.01	0.01	0.01	0.01	0.06	0.01		0.01	0.01
05/10/1999		0.01	0.01	0.01	1.05	0.01	0.01	0.11	0.01

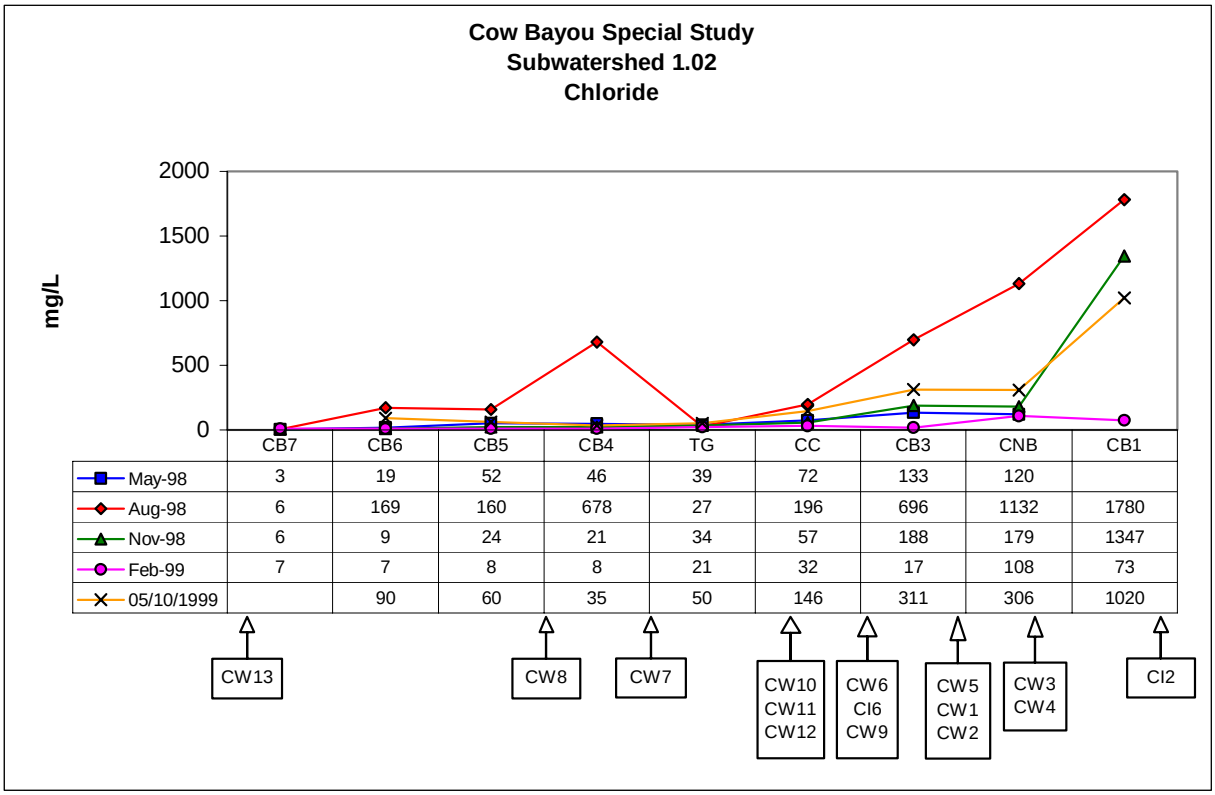


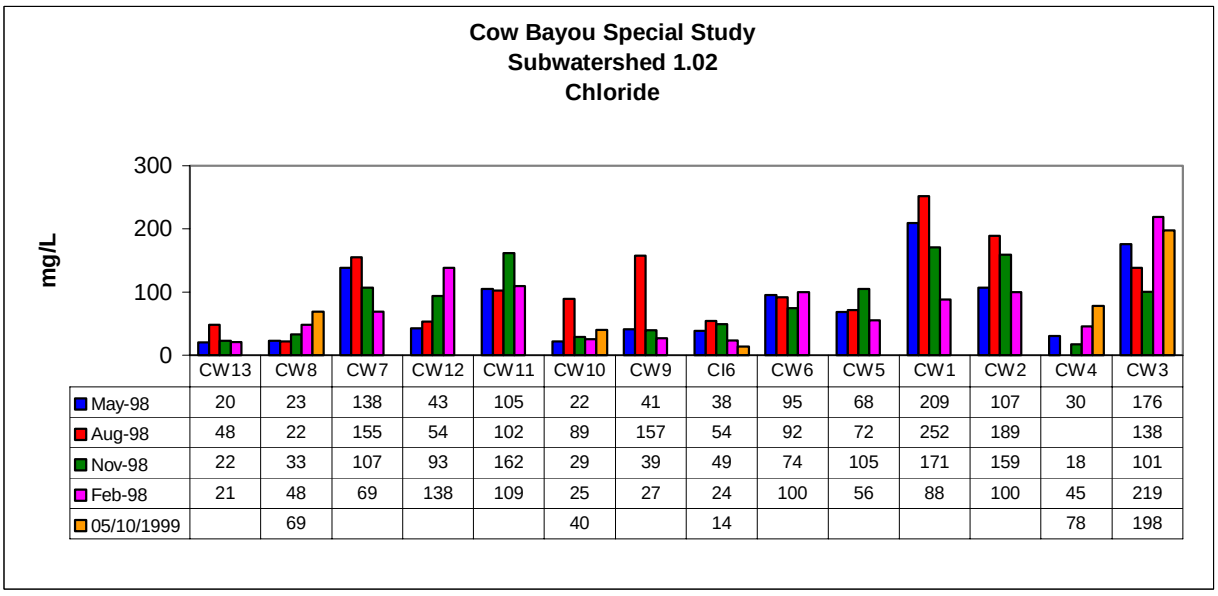
	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
08/07/1998	2.83	1.94	12.20	0.13	1.85	5.11	3.98	1.48		0.35	5.92	3.44		2.15	0.25
11/13/1998	1.44	1.17	1.63	2.80	4.34	1.41	0.57	0.10	6.81	2.35	1.48	4.11	0.50	3.01	0.17
05/10/1999		6.63				10.20		0.64					3.24	3.40	

Chloride

Limits for chloride levels are set in TSWQS, but not for tidally influenced segments. High levels of chlorides (600 mg/L) can negatively impact freshwater streams and higher levels (1200 mg/L) can be toxic to fish. Fluctuating levels of chlorides are normal in estuarine systems and the aquatic community is adapted for these conditions. The high chloride values in the stream sites appear to be due to natural conditions. The highest values were found at the most tidally influenced sites. Chlorides were high at the discharge sites, but do not appear to impact the stream sites.

Special Study on Subwatershed 1.02 – Cow Bayou

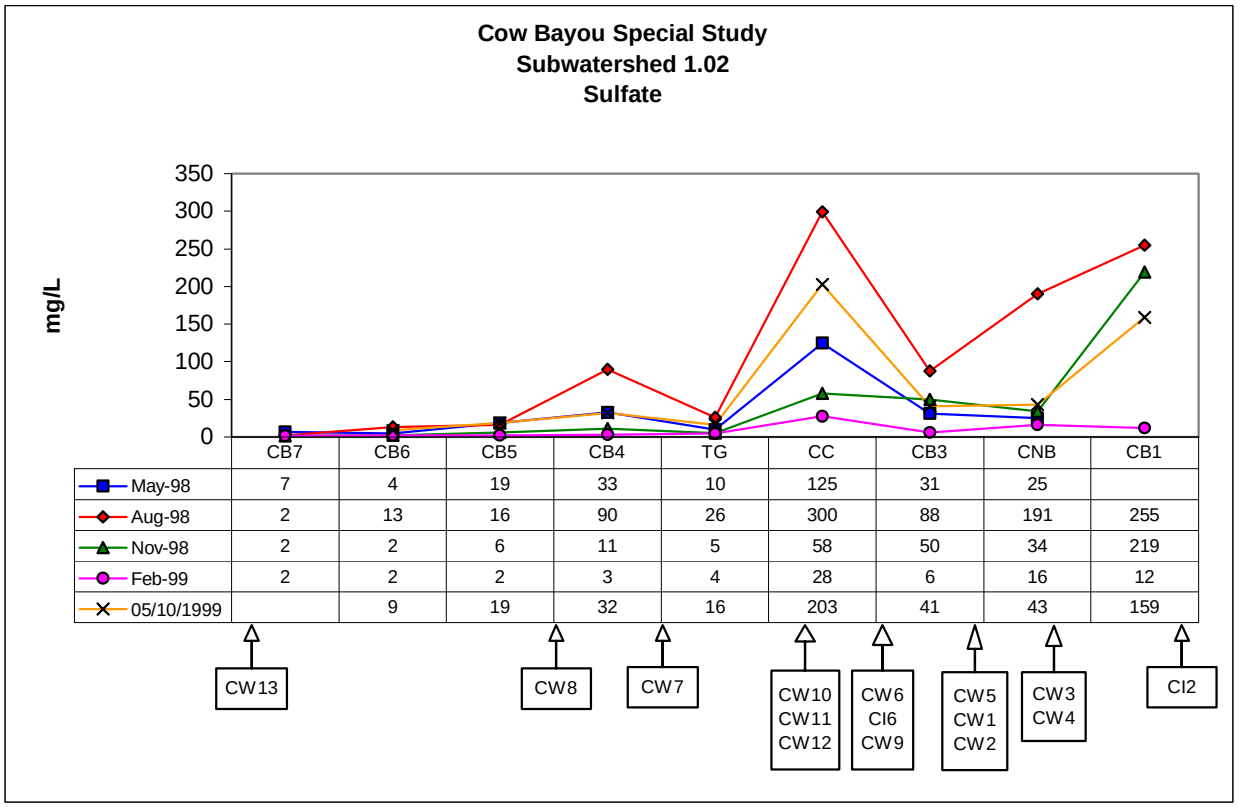




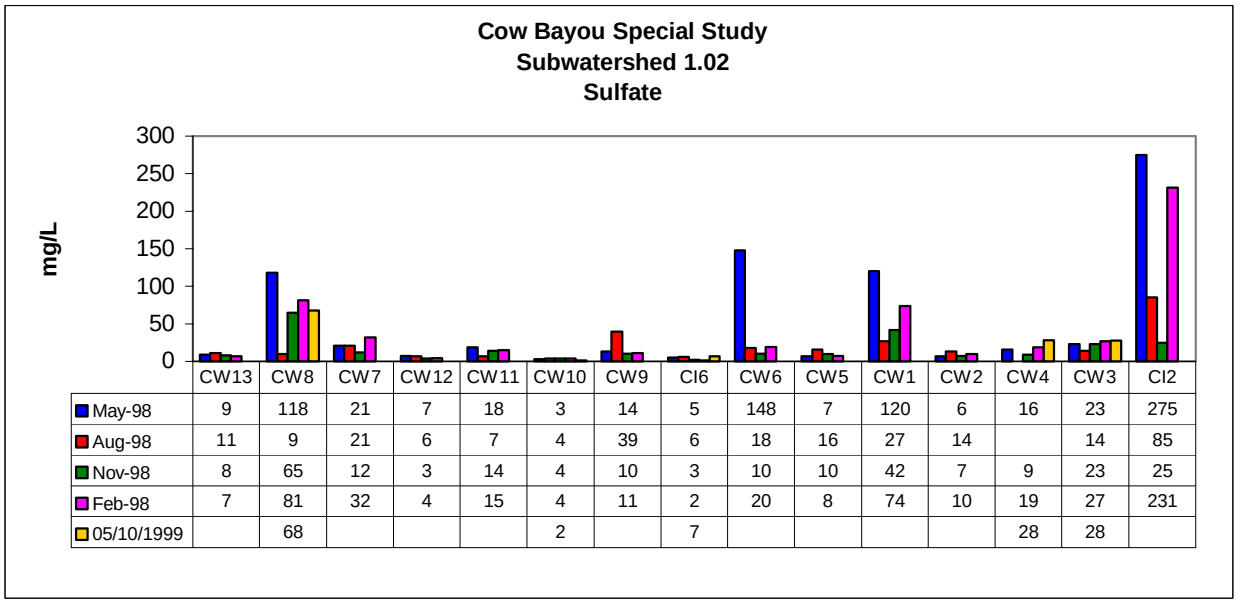
Sulfate

Sulfate limits are set in TSWQS for designated segments other than tidally influenced segments. Sulfates are not considered toxic to plants or animals at normal concentrations. Levels of sulfate in Sabine Basin streams are generally well below 100 mg/L. Higher levels in streams can result from the breakdown of leaves that are washed into the stream. Values for sulfate in the stream sites were highest at sites CC and CB1, but appear to be due to natural conditions. The values increased as tidal influence increased downstream. Sulfate levels were generally low at the discharge sites, but high values were observed at CW8, CW6, and CI2. No impact from the discharge sites was observed at the stream sites.

Special Study on Subwatershed 1.02 – Cow Bayou



	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
May-98	7	4	19	33	10	125	31	25	
Aug-98	2	13	16	90	26	300	88	191	255
Nov-98	2	2	6	11	5	58	50	34	219
Feb-99	2	2	2	3	4	28	6	16	12
05/10/1999		9	19	32	16	203	41	43	159



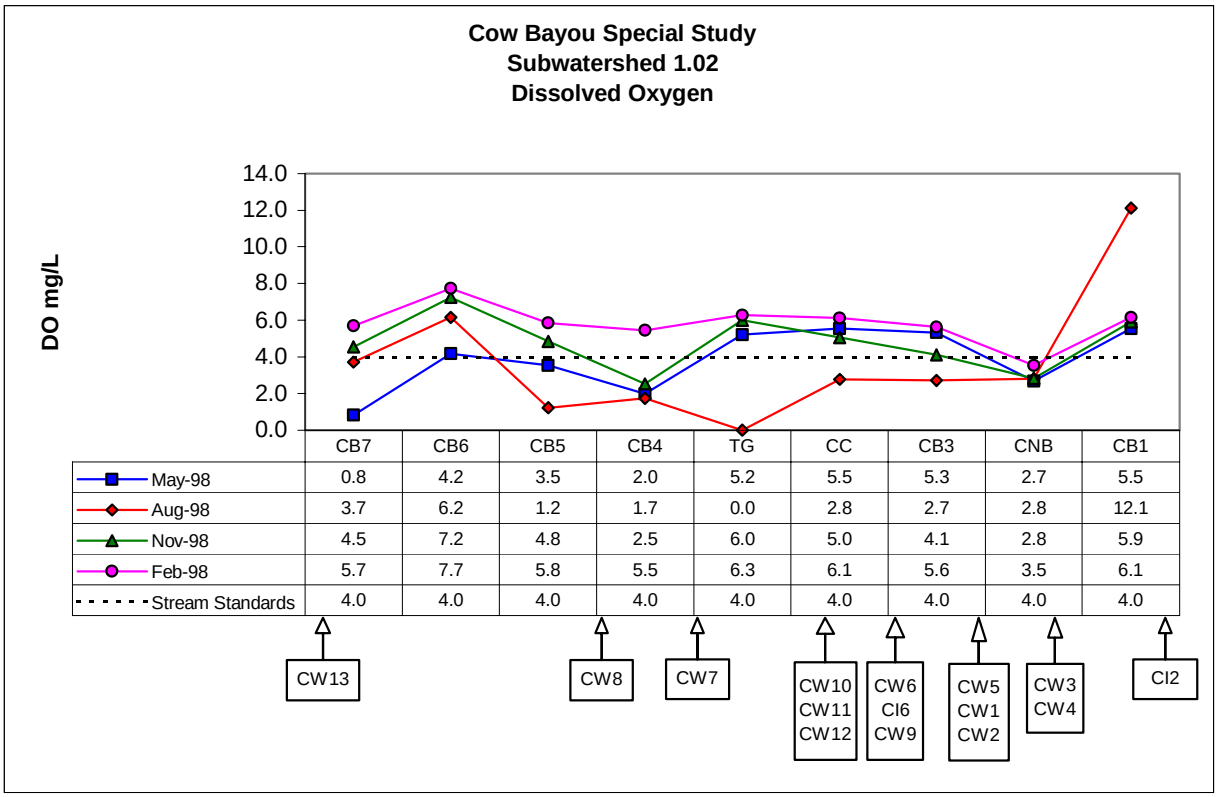
	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
May-98	9	118	21	7	18	3	14	5	148	7	120	6	16	23	275
Aug-98	11	9	21	6	7	4	39	6	18	16	27	14		14	85
Nov-98	8	65	12	3	14	4	10	3	10	10	42	7	9	23	25
Feb-98	7	81	32	4	15	4	11	2	20	8	74	10	19	27	231
05/10/1999		68				2		7					28	28	

Dissolved Oxygen

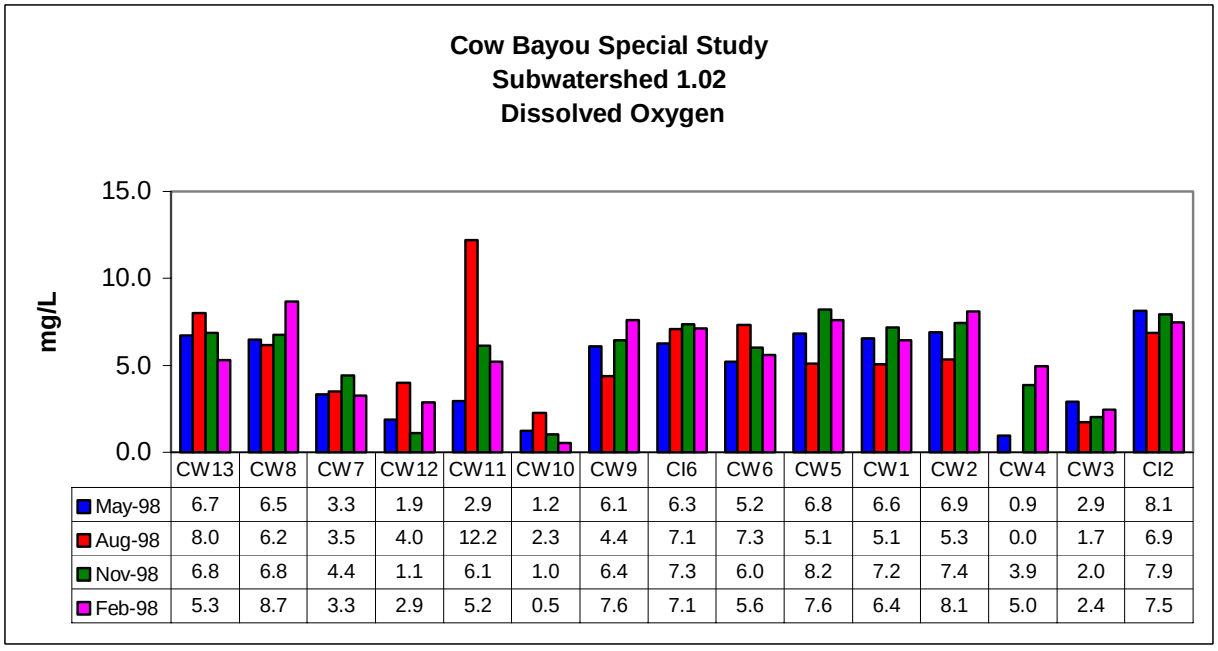
Adequate dissolved oxygen is necessary for a healthy aquatic community and to provide for aerobic life forms that carry on natural stream purification processes. As dissolved oxygen levels in water drop below 5.0 mg/L, aquatic life is put under stress. The lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/L for a few hours can result in large fish kills. Stream standards for dissolved oxygen are set as the minimum average value for a 24-hour period. The daily average set in TSWQS is 4.0 mg/L with a minimum instantaneous value of 3.0 mg/L. Values at most stream sites were above 3.0 mg/L during three out of the four routine sampling events, but sites CB4 and CNB were only above the minimum level one time. Low levels were observed at least once at every site except sites CB6 and CB1, which were always above the minimum standard. During rainfall events, dissolved oxygen readings below 3.0 mg/L were observed at CB5, CB4, TG, and CNB. Site CB4 was only above the minimum level once. Most of the oxygen problems appear to be related to non-point source pollution such as on-site septic systems and other human activities. Impacts from point sources appear to be slight, but the stressed system lacks the assimilative capacity to handle waste loads.

At the discharge sites, low dissolved oxygen values were routinely recorded at Stations CW12, CW10, CW4, and CW3. A high value (12.2 mg/L) was recorded at Station CW11, but the average for all of the discharge sites was 5.3 mg/L. Minimum dissolved oxygen requirements for dischargers range from 4.0 mg/L to 2.0 mg/L, however several of the discharges were observed at levels below their minimum requirements. Dissolved oxygen at the discharge sites during rainfall events showed results similar to those during quarterly sampling. Low values were observed at CW12, CW10, and CW4.

Special Study on Subwatershed 1.02 – Cow Bayou

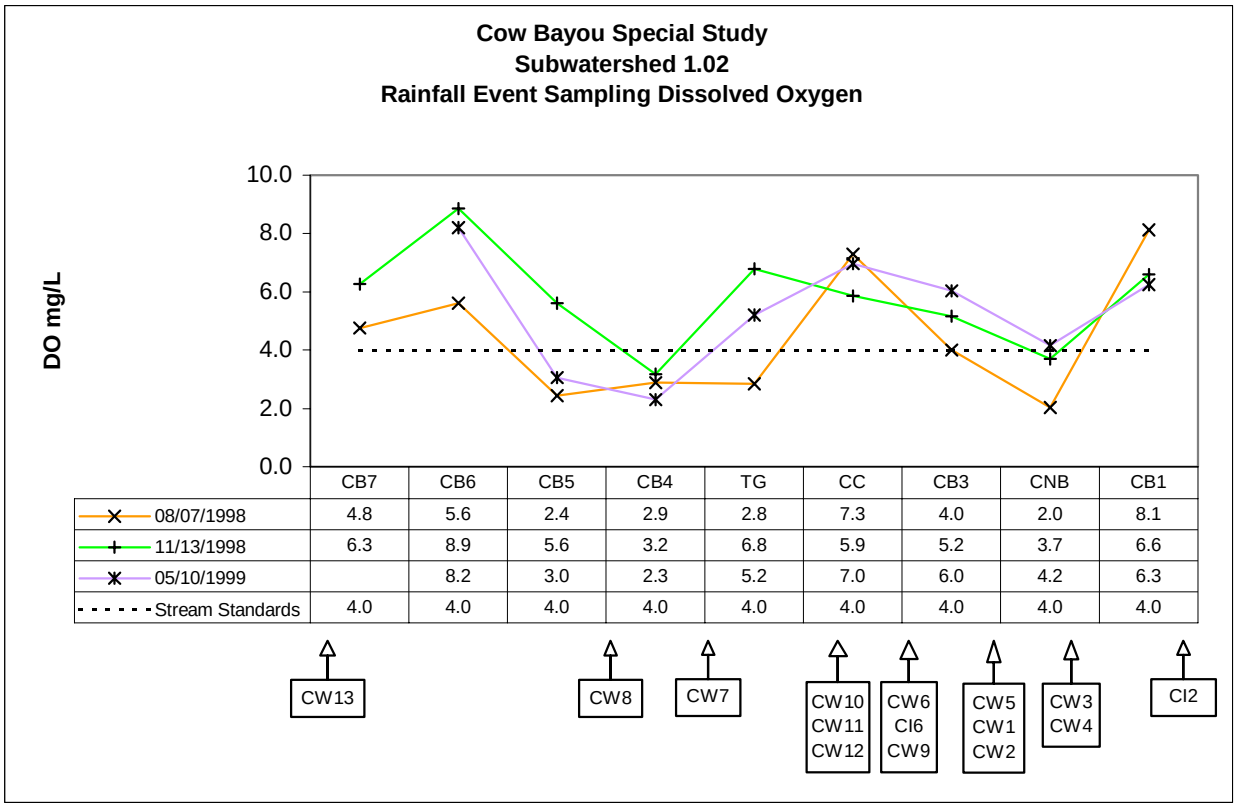


	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
May-98	0.8	4.2	3.5	2.0	5.2	5.5	5.3	2.7	5.5
Aug-98	3.7	6.2	1.2	1.7	0.0	2.8	2.7	2.8	12.1
Nov-98	4.5	7.2	4.8	2.5	6.0	5.0	4.1	2.8	5.9
Feb-98	5.7	7.7	5.8	5.5	6.3	6.1	5.6	3.5	6.1
Stream Standards	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

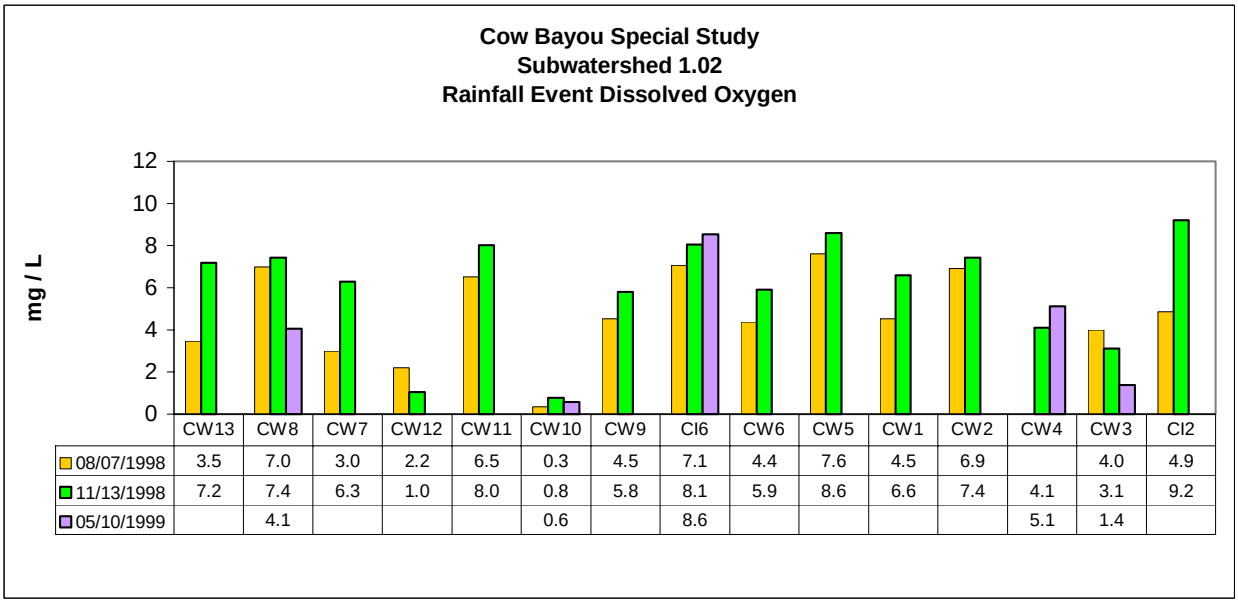


	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
May-98	6.7	6.5	3.3	1.9	2.9	1.2	6.1	6.3	5.2	6.8	6.6	6.9	0.9	2.9	8.1
Aug-98	8.0	6.2	3.5	4.0	12.2	2.3	4.4	7.1	7.3	5.1	5.1	5.3	0.0	1.7	6.9
Nov-98	6.8	6.8	4.4	1.1	6.1	1.0	6.4	7.3	6.0	8.2	7.2	7.4	3.9	2.0	7.9
Feb-98	5.3	8.7	3.3	2.9	5.2	0.5	7.6	7.1	5.6	7.6	6.4	8.1	5.0	2.4	7.5

Special Study on Subwatershed 1.02 – Cow Bayou



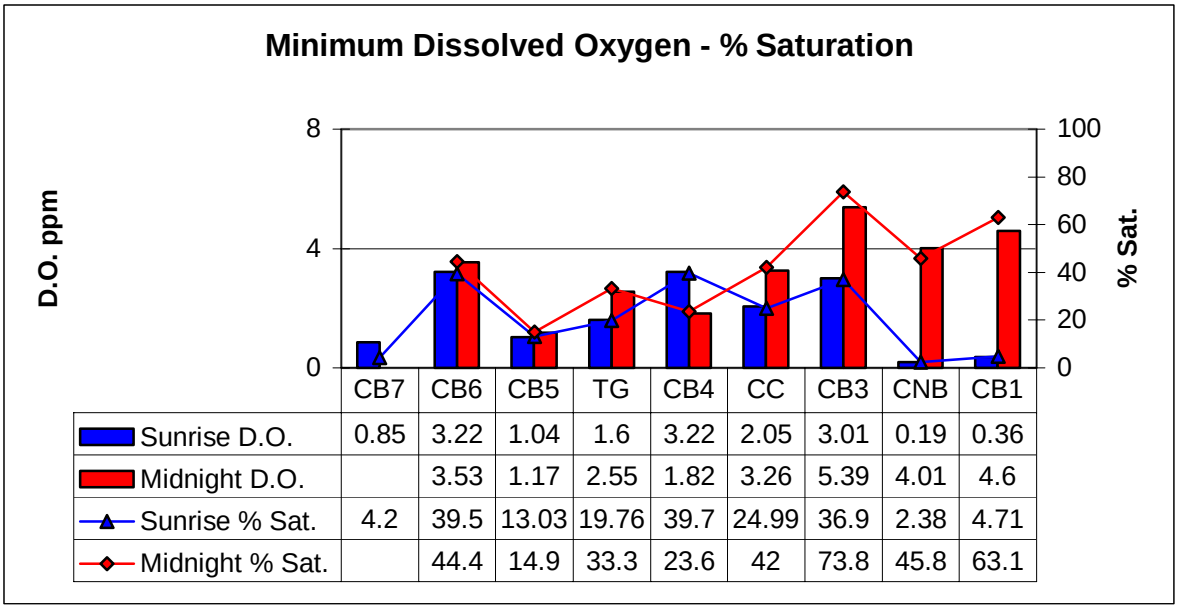
	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
08/07/1998	4.8	5.6	2.4	2.9	2.8	7.3	4.0	2.0	8.1
11/13/1998	6.3	8.9	5.6	3.2	6.8	5.9	5.2	3.7	6.6
05/10/1999		8.2	3.0	2.3	5.2	7.0	6.0	4.2	6.3
Stream Standards	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0



	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
08/07/1998	3.5	7.0	3.0	2.2	6.5	0.3	4.5	7.1	4.4	7.6	4.5	6.9		4.0	4.9
11/13/1998	7.2	7.4	6.3	1.0	8.0	0.8	5.8	8.1	5.9	8.6	6.6	7.4	4.1	3.1	9.2
05/10/1999		4.1				0.6		8.6					5.1	1.4	

Minimum Dissolved Oxygen

Dissolved oxygen concentrations cycle from highs to lows with the cycle of daylight and darkness. In turbid waters such as Cow Bayou, diffusion of atmospheric oxygen can be the major source of oxygen for the stream. Aquatic plants also produce oxygen for the stream in the presence of sufficient light and the oxygen is diffused into the water body. During the periods of darkness, the plants and animals in the aquatic community can consume more oxygen than the stream can supply. Dissolved oxygen is usually at its lowest level just prior to daylight. Dissolved oxygen measurements were taken within two hours of sunrise at selected stream sites to determine minimum values. Additional readings were taken at selected stream sites near midnight. The sunrise dissolved oxygen values were particularly low at Stations CB7, CB5, CNB, and CB1. This would indicate that extremely stressful conditions exist on a routine basis at these sites. The midnight readings at Stations CNB and CB1 were well above minimum standards.



	CB7	CB6	CB5	TG	CB4	CC	CB3	CNB	CB1
Sunrise D.O.	0.85	3.22	1.04	1.6	3.22	2.05	3.01	0.19	0.36
Midnight D.O.		3.53	1.17	2.55	1.82	3.26	5.39	4.01	4.6
Sunrise % Sat.	4.2	39.5	13.03	19.76	39.7	24.99	36.9	2.38	4.71
Midnight % Sat.		44.4	14.9	33.3	23.6	42	73.8	45.8	63.1

Fecal Coliform

Coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. Their normal function is to aid in the digestion of food. Fecal coliform bacteria are a specific subgroup of this collection and the most common member is *Escherichia coli*. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals.

The presence of fecal coliform bacteria in aquatic environments indicates contamination with the fecal material of man or other animals. The water may also be contaminated by pathogens or disease producing bacteria or viruses, which can exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water due to the overflow of domestic sewage or nonpoint sources of human and animal waste.

The TSWQS fecal coliform limit in water used for contact recreation is 200 colonies per 100 mL of water. This limit is a geometric mean, which is based on a minimum of five samples collected in a 30-day period. Although stream sites CB7, CB6, CB4, and CB3 were below the limit at least three out of the four sampling periods, violations of stream standards occurred at all of these sites. The geometric means were in violation of stream standards at stream sites TG, CC, CNB, and CB1 for most of the sampling periods. The results from the differentiation tests indicated that all of the bacteria present from the fecal coliform group were *Escherichia coli*. At the discharge sites, the highest geometric mean for fecal coliform was 135,600-colonies/100 mL at CW3. Stations CW10and CW4 were consistently above the 200 limit. Station CW8 was below 200-colonies/100 mL only one sampling period. Violations of stream standards occurred at CW13, CW12, CW11, CW10, CW8, CW4, CW3, CI6, and CI2. Sites CW7, CW6, CW5, and CW2 were never in violation of stream standards.

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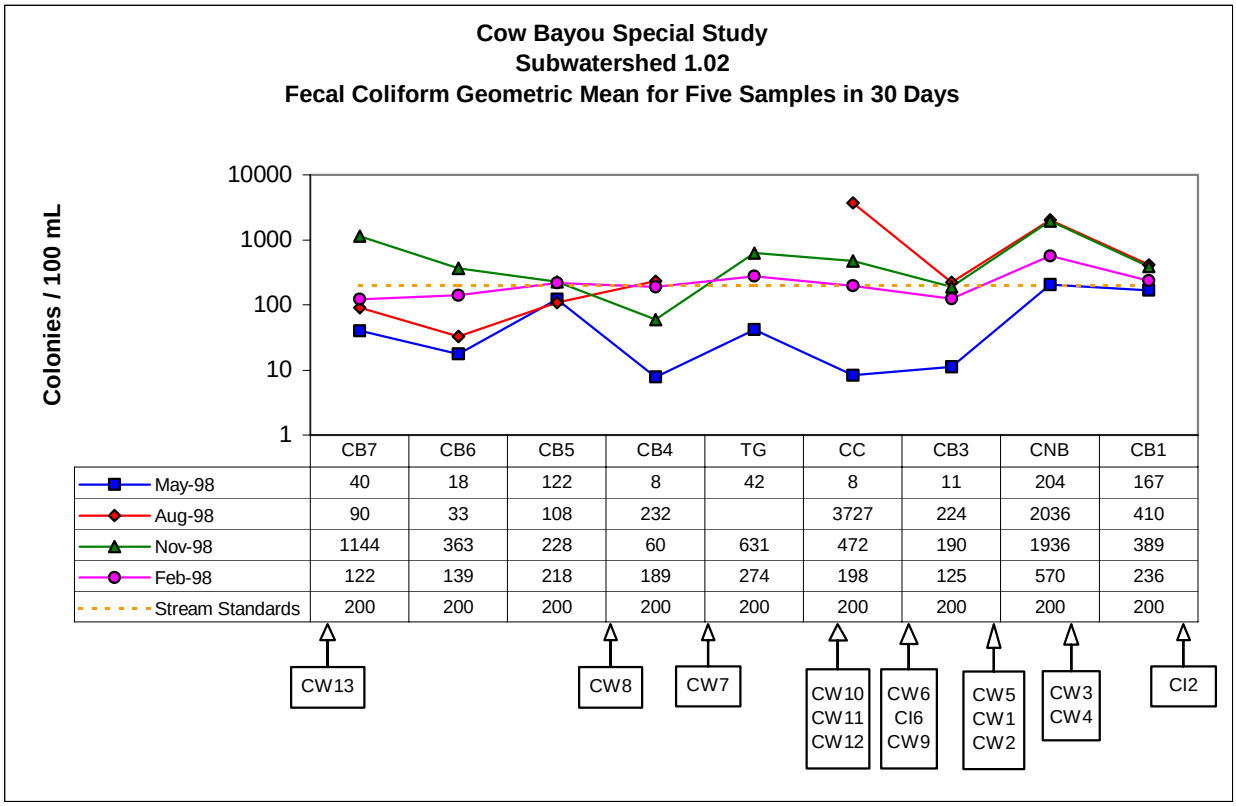
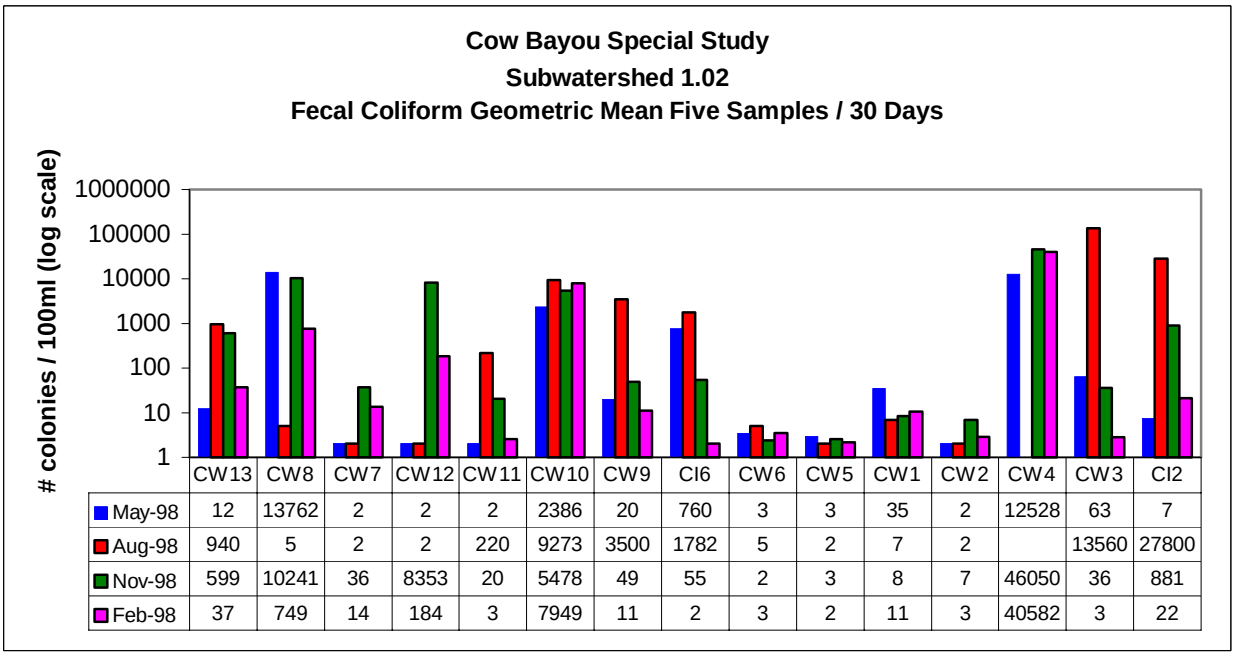


	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
May-98	40	18	122	8	42	8	11	204	167
Aug-98	90	33	108	232		3727	224	2036	410
Nov-98	1144	363	228	60	631	472	190	1936	389
Feb-98	122	139	218	189	274	198	125	570	236
Stream Standards	200	200	200	200	200	200	200	200	200

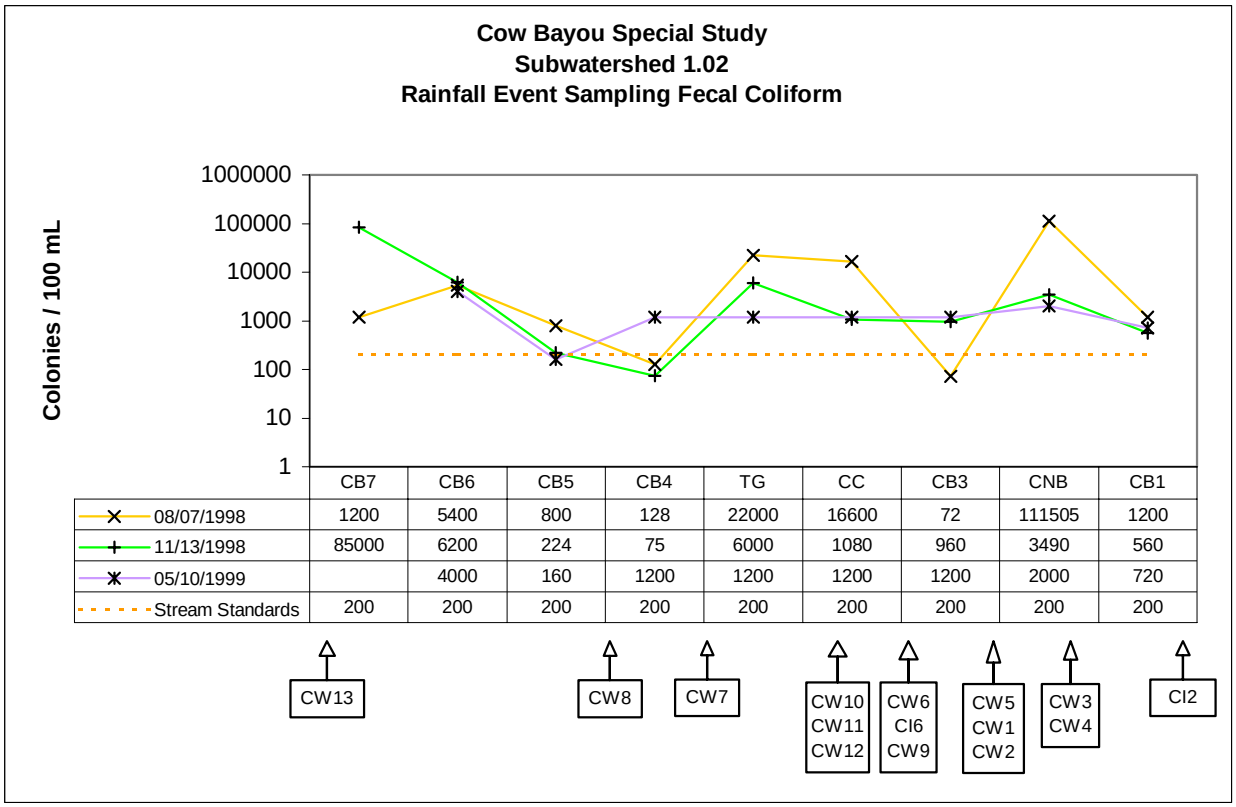


	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
May-98	12	13762	2	2	2	2386	20	760	3	3	35	2	12528	63	7
Aug-98	940	5	2	2	220	9273	3500	1782	5	2	7	2		13560	27800
Nov-98	599	10241	36	8353	20	5478	49	55	2	3	8	7	46050	36	881
Feb-98	37	749	14	184	3	7949	11	2	3	2	11	3	40582	3	22

Fecal Coliform - Rainfall Events

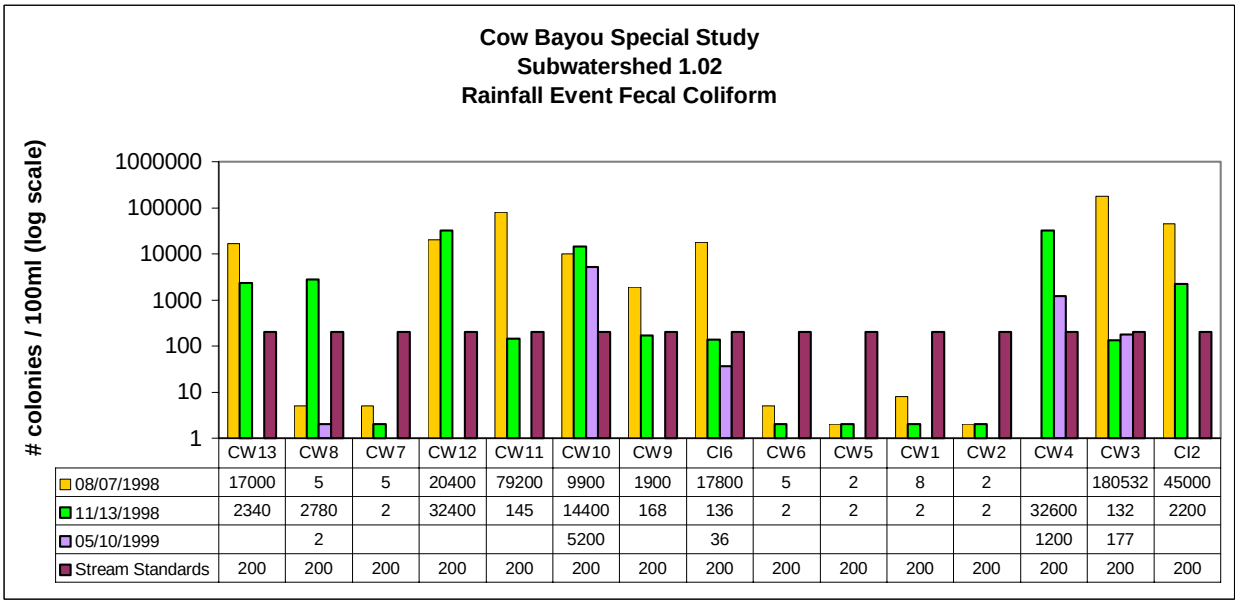
Rainfall events typically cause an elevation of fecal coliform levels in streams due to contaminated runoff. Fecal coliform levels were generally higher during rainfall events than the levels found during quarterly sampling. Every stream site was above the stream standards at least once during rainfall sampling events. Stream standard violations were observed during all rainfall events at stream sites CB7, CB6, TG, CC, CNB, and CB1. Stream sites CB5and CB3 were in violation of stream standards for two of the three rainfall events. Station CB4 was above the 200 limit only once. The elevated values during rainfall events indicate contamination from non-point sources. During rainfall events, the permitted discharge sites CW13, CW 12, CW10, CW4, and CI2 were in violation of stream standards every time. Stream standard violations were also observed at least once at sites CW11, CW9, CW8, and CI6. Values at sites CW7, CW6, CW5, and CW2 were always less than 200-colonies/100 mL.

Special Study on Subwatershed 1.02 – Cow Bayou



	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
08/07/1998	1200	5400	800	128	22000	16600	72	111505	1200
11/13/1998	85000	6200	224	75	6000	1080	960	3490	560
05/10/1999		4000	160	1200	1200	1200	1200	2000	720
Stream Standards	200	200	200	200	200	200	200	200	200

CW13 | CW8 | CW7 | CW10 CW11 CW12 | CW6 CI6 CW9 | CW5 CW1 CW2 | CW3 CW4 | CI2

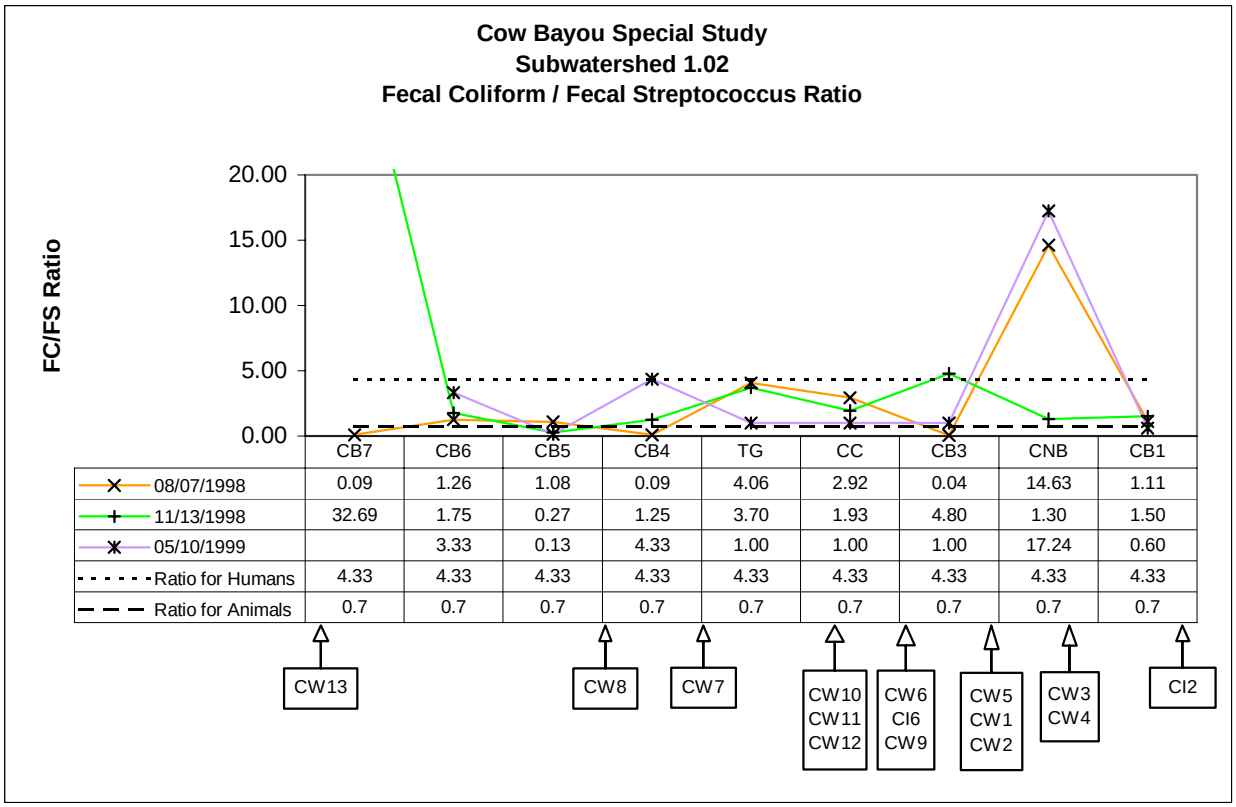


	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
08/07/1998	17000	5	5	20400	79200	9900	1900	17800	5	2	8	2		180532	45000
11/13/1998	2340	2780	2	32400	145	14400	168	136	2	2	2	2	32600	132	2200
05/10/1999		2				5200		36					1200	177	
Stream Standards	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200

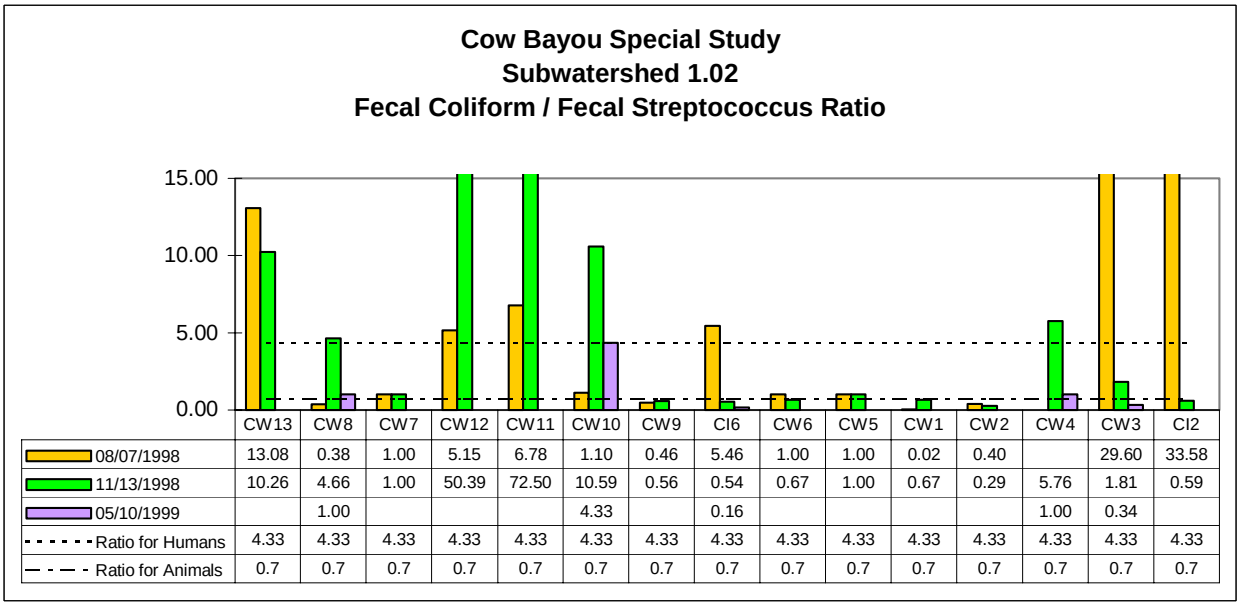
Fecal Coliform/Fecal Streptococcus Ratio

Fecal coliform to fecal streptococcus ratios were measured during rainfall events to help determine the source of fecal contamination. Contamination due to human sources should show ratios at 4.3 or higher and animal sources would have a ratio of 0.7 or less. None of the stream site ratios were consistently below 0.7, and CB5 was the only site consistently less than 4.33. These results would imply most of the contamination in the runoff contained human waste rather than animal waste. Ratios of fecal coliform to fecal streptococcus during rainfall events were consistently above the ratio for humans at sites CW13, CW12, and CW11. Ratios below 4.3 were observed at sites CW7, CW9, CW6, CW5, CW1, and CW2 for each rainfall event. The results indicate some impact on the stream sites could be due to the discharges, but much of the impact is from non-point sources.

Special Study on Subwatershed 1.02 – Cow Bayou



	CB7	CB6	CB5	CB4	TG	CC	CB3	CNB	CB1
08/07/1998	0.09	1.26	1.08	0.09	4.06	2.92	0.04	14.63	1.11
11/13/1998	32.69	1.75	0.27	1.25	3.70	1.93	4.80	1.30	1.50
05/10/1999		3.33	0.13	4.33	1.00	1.00	1.00	17.24	0.60
Ratio for Humans	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33
Ratio for Animals	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7



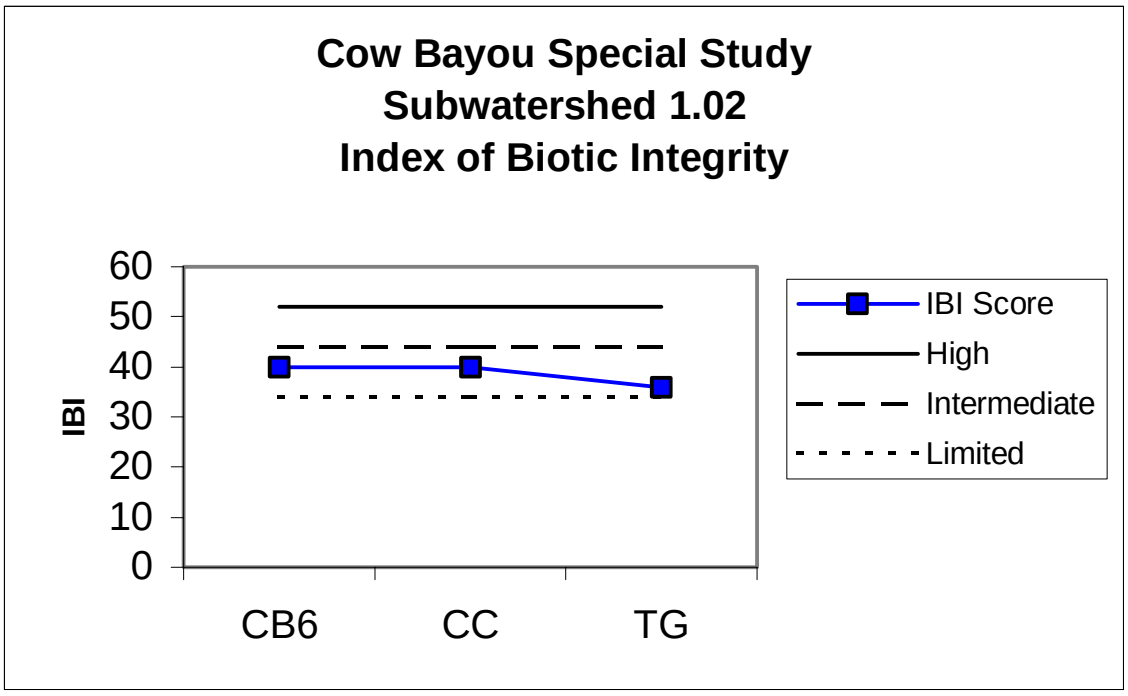
	CW13	CW8	CW7	CW12	CW11	CW10	CW9	CI6	CW6	CW5	CW1	CW2	CW4	CW3	CI2
08/07/1998	13.08	0.38	1.00	5.15	6.78	1.10	0.46	5.46	1.00	1.00	0.02	0.40		29.60	33.58
11/13/1998	10.26	4.66	1.00	50.39	72.50	10.59	0.56	0.54	0.67	1.00	0.67	0.29	5.76	1.81	0.59
05/10/1999		1.00				4.33		0.16					1.00	0.34	
Ratio for Humans	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33
Ratio for Animals	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

Rapid Bioassessments

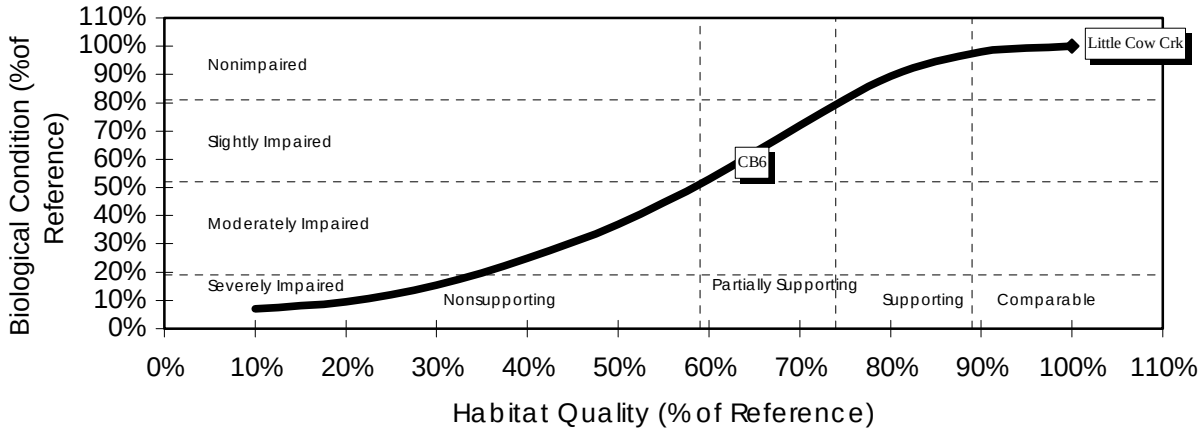
The TSWQS establishes five subcategories for Aquatic Life Use in waterbodies. The Cow Bayou Subwatershed is designated as having a High Aquatic Life Use and should have a dissolved oxygen level of 4.0 mg/L as a 24-hour mean and a minimum of 3.0 mg/L. The habitat should be highly diverse to provide adequate living conditions and space for the aquatic organisms. The organisms should include the assemblage of species found in similar habitats. Species that are sensitive to polluted conditions should be present as well as a balance of numerous types of species. Rapid Bioassessments (RBA) are utilized to determine the conditions of the aquatic community in waterbodies.

The RBA used in the Cow Bayou Subwatershed examined the fish community in the stream. The RBA for site CB6 indicated an intermediate level of diversity in fish species. Although there was an abundance of fish present, there was little diversity and not enough sensitive species. An intermediate level of diversity was observed for Cole Creek (CC), which has an intermediate classification under the general criteria of the TSWQS. There were fish present in large enough numbers, but sensitive species were not found in large enough numbers. Terry Gully (TG) showed a limited/intermediate level of diversity and has an intermediate rating in TSWQS also. These results indicate the biological conditions in the tributaries are less than optimal, but not beyond what would be expected. The results from the main-stem indicate biological conditions are well below what should be present in the stream.

A comparison was also made between the available habitat and the fish found in the stream. This type of comparison utilizes a reference site to show the correlation between the habitat and biological conditions in an unpolluted stream. The biological conditions at CB6 correlated well with the available habitat. While the biological conditions in Cow Bayou were only about half that of the reference site, the habitat was also only about half that of the reference site.

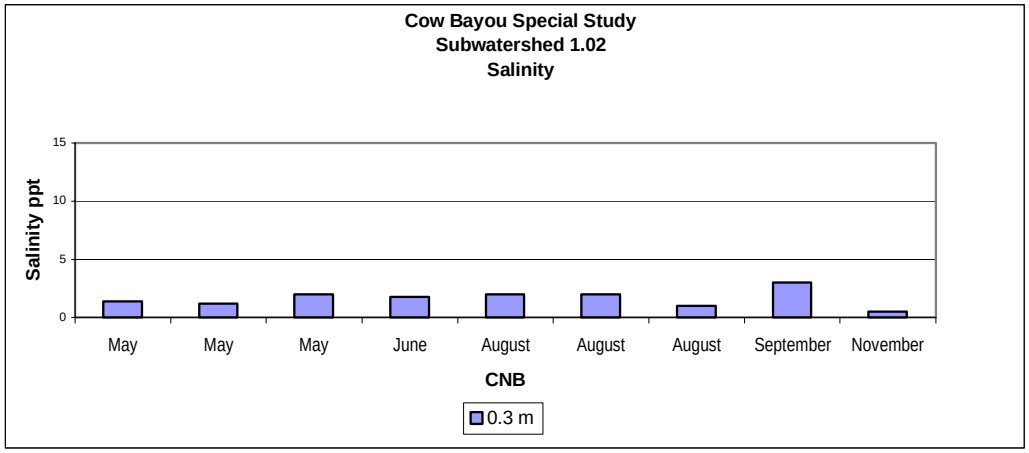


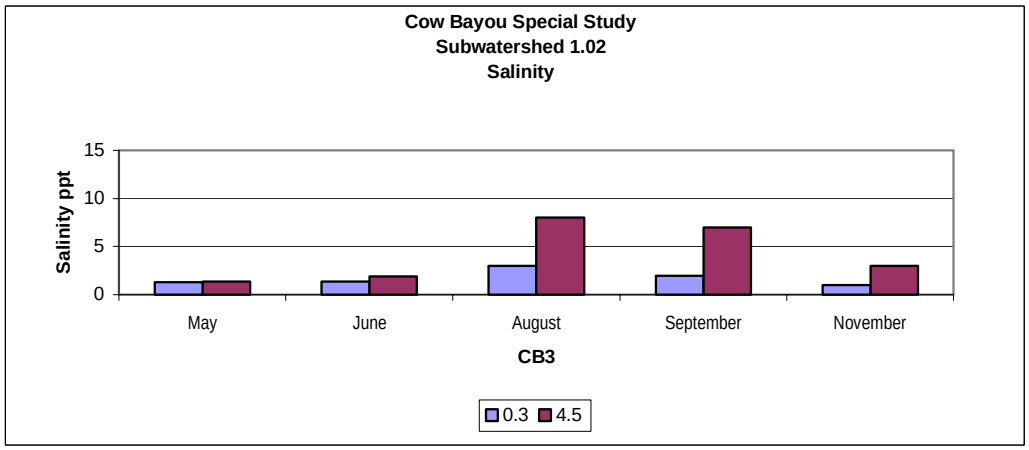
Cow Bayou July 1998

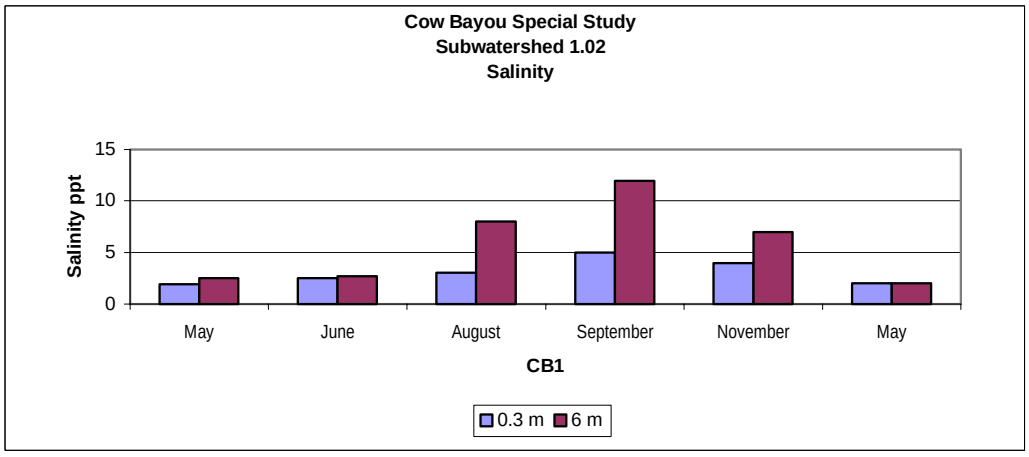


Salinity

The salinity ranged from 12 parts per thousand (ppt) at Station CB1 to 1 ppt at Station CB3. The salinity measurements at Stations CB1 and CB3 showed higher readings at the greater depths. This indicates strong tidal influence at these sites. None of the other stream sites showed salinity.

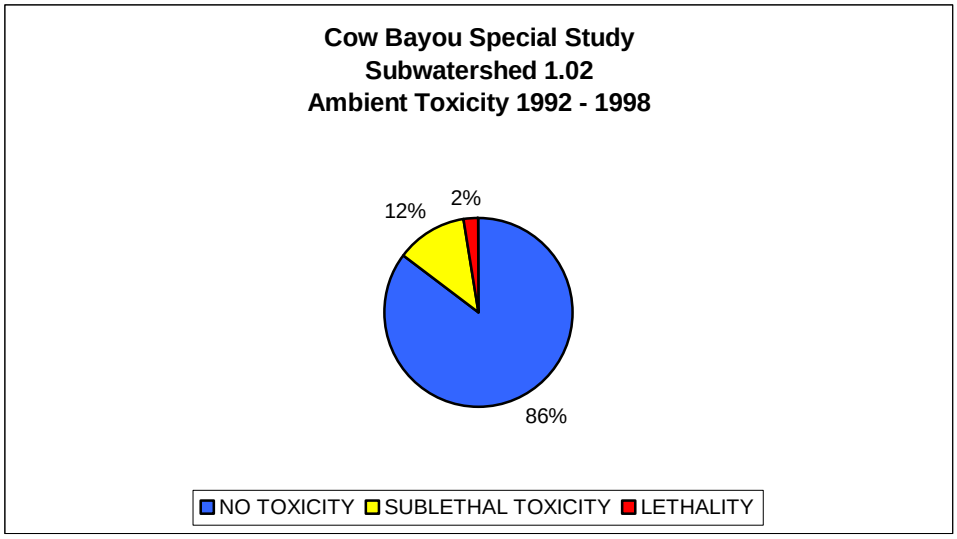






Ambient Toxicity

Ambient toxicity tests began in the Cow Bayou Subwatershed in 1992 and indicated some problems with toxicity. By 1998, 41 toxicity tests were conducted on Cow Bayou from and the overall results indicate no toxicity in 86% of the tests. Only 2% of the tests showed lethal toxicity to the test organisms. These results show toxicity is not a problem in the Cow Bayou Subwatershed. Ambient toxicity tests were performed on samples from discharge sites where no toxicity data was available from previous tests required by TNRCC or EPA. Sites CI2 and CI6 were tested for toxicity and no toxicity problems were found. The results indicate there are no toxicity problems in the stream due to impact from these permitted discharges.



Conclusions and Recommendations

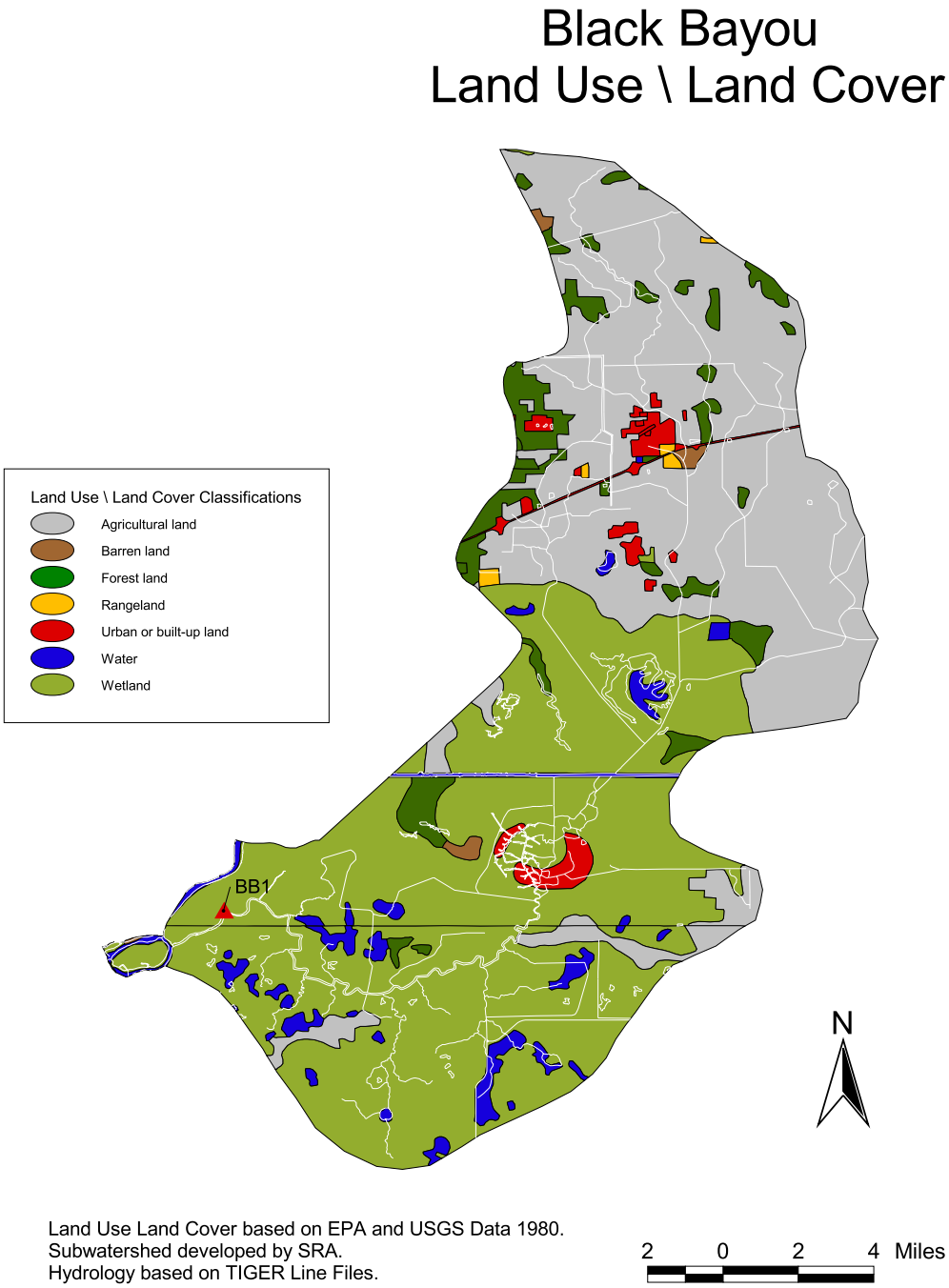
Water quality conditions in the Cow Bayou watershed are limited by the tidal nature of the system, the turbidity due to natural conditions, and the impact from human activities. The dissolved oxygen available for aquatic wildlife is being impacted negatively by point and nonpoint sources. Although the impact from point sources in this study appears to be minimal, the cumulative effect when combined with nonpoint source runoff is a higher oxygen demand than the waterbody can assimilate. The effect of human activities, including point and nonpoint sources, is difficult to measure in tidally influenced streams since there is not always a clear upstream or downstream site to gauge the impact. A comparison can be made to Black Bayou, which is located southeast of Cow Bayou in a sparsely populated area in southwest Louisiana. Monitoring data was collected from a site (BB1) near the mouth of Black Bayou, upstream of the Sabine Lake confluence. The location of this site is similar to the location of CB1 in Cow Bayou with the primary difference being the lack of impact from human activities. The comparison is most applicable to the lower end of both Subwatersheds.

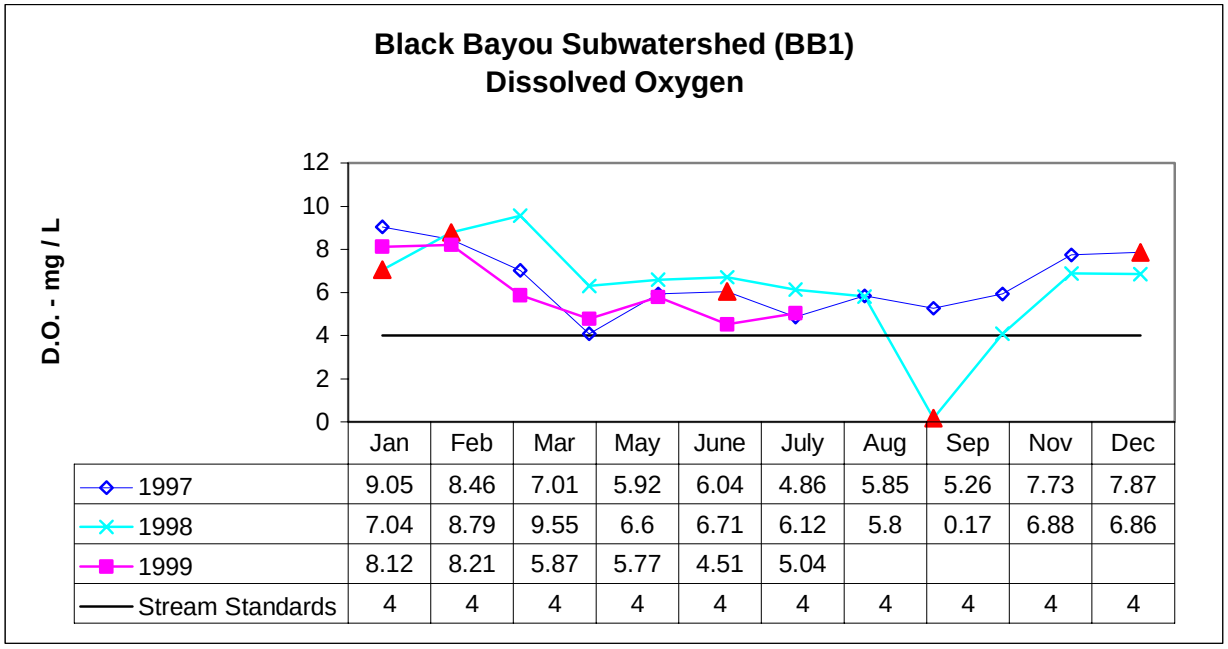
The average value for dissolved oxygen (DO) at BB1 was 6.3 mg/L and was less than 4mg/L only once out of 31 sampling events. This compares well with the average value of 6.0 mg/L at CB1, however the level was less than 4.0 mg/L twice out of 21 sampling events. The average DO was 4.7 mg/L at Station CB3 and 2.9 mg/L at CB4. These sites are considerably further upstream from CB1, but the primary difference is their proximity to non-point sources of pollution. The DO level at site BB1 dropped below 4.0 mg/L just after a major rainfall event and the decrease was probably due to runoff from marsh areas that can sometimes have standing pools of low oxygen water. This is a natural condition and the site appeared to recover quickly with no long-term effects. Other sampling events following rainfall periods did not exhibit the same phenomenon.

Fecal coliform levels should normally be low in streams even if natural conditions cause occasional high concentrations. Natural conditions that can raise fecal coliform levels include flocks of migratory birds as well as other natural concentrations of wild animal populations. High levels of fecal coliform due to natural conditions are usually associated with runoff from heavy rains after a period of relatively dry weather. Fecal coliform values in Cow Bayou appear to be elevated from both point and nonpoint sources. Geometric means were above the TSWQS

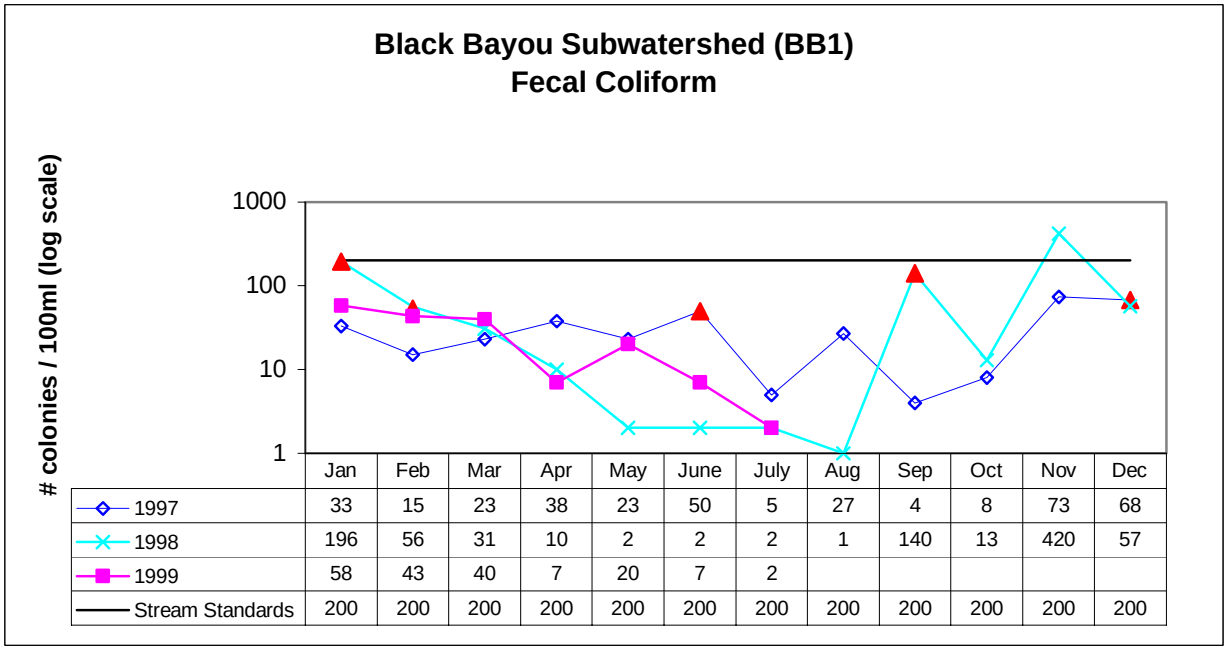
limit of 200 colonies at Sites CB1, TG, and CNB during routine sampling as well as rainfall events. Elevated values were detected at the stream sites during every rainfall event. Fecal coliform values in Black Bayou exceeded the 200-colony limit only once out of 31 sampling events and never during a rainfall event. The fecal coliform geometric mean for the period from January 1997 to July 1999 at BB1 was 19 colonies per 100mL.

Figure 4. Land Use in the Black Bayou Watershed





	Jan	Feb	Mar	May	June	July	Aug	Sep	Nov	Dec
1997	9.05	8.46	7.01	5.92	6.04	4.86	5.85	5.26	7.73	7.87
1998	7.04	8.79	9.55	6.6	6.71	6.12	5.8	0.17	6.88	6.86
1999	8.12	8.21	5.87	5.77	4.51	5.04				
Stream Standards	4	4	4	4	4	4	4	4	4	4



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1997	33	15	23	38	23	50	5	27	4	8	73	68
1998	196	56	31	10	2	2	2	1	140	13	420	57
1999	58	43	40	7	20	7	2					
Stream Standards	200	200	200	200	200	200	200	200	200	200	200	200

Rainfall events are represented by the red triangles (▲).

While nutrients were not significantly higher at the stream sites in Cow Bayou, high nutrient values were observed at several of the permitted discharge sites. The small impact on the stream from the discharge sites is likely due to the low flows of the discharges combined with

assimilation of the nutrients into the stream. This assimilation impacts the stream in the form of excessive aquatic vegetation.

The present wastewater systems in the Cow Bayou watershed are not adequately preventing water quality degradation in the stream. Much of the populated areas are not currently being served by treatment plants and must rely on traditional on-site systems. These systems have been shown to be completely inadequate for the soil typical of this area and the 55 plus inches of average annual rainfall. Newly constructed homes in the area are required to have aeration systems and older homes must be upgraded when sold. This process could take decades to replace enough systems to adequately reduce the impact from rainfall runoff.

New wastewater treatment systems have been constructed since the beginning of this special study. Preliminary plans have also been made to add significant portions of populated areas to existing treatment plants. All these improvements will help, but to sufficiently reduce the impact on Cow Bayou the highly populated areas should be served by a system large enough to eliminate the stress on the natural system. All of the entities in the Orange County area need to collectively work together and make an application to the Texas Water Development Board to study the feasibility of a regional treatment plant. This alternative would significantly reduce the anthropogenic pollutant loads. The system must address infiltration and wet-weather problems that exacerbate non-point impacts during rainfall events.

A regional wastewater system should also address discharge of treated wastewater into a constructed wetland to further reduce any impact to the receiving stream. Artificial wetlands have been shown to function well in southeast Texas. Constructed wetlands such as the city of Beaumont's not only improve water quality in the stream, but also offer an eco-tourism bonus to the area.